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ABSTRACT

These volumes are, respectively, the self-instructional student manual and the teacher manual that cover the second set of training topics in this course for television repair technicians. Both contain identical explanations of the structure and function of the elements of the video signal processing circuit (the tuner, video intermediate frequency, video detector, AGC circuit, and video amplifier circuit), and both contain circuit diagrams and functional block diagrams. (CML)

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TV TROUBLE-SHOOTING MANUAL
VOLUMES 5-6

Part 2: Video Signal Processing Circuit

Student and Instructor's Manuals

Asian and Pacific Skill Development Programme
Islamabad, Pakistan

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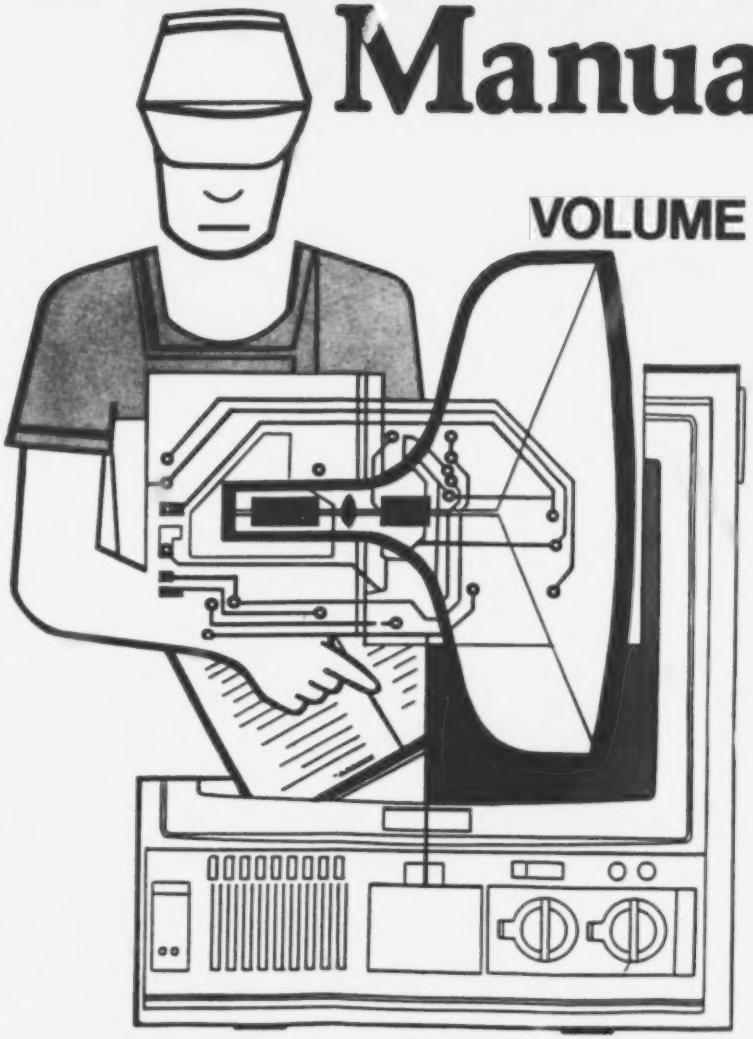
TV Trouble-shooting Manual

VOLUME



BY MASAAKI MUKAI AND RYOZO KOBAYASHI

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TV Trouble-shooting Manual

VOLUME 5

BY MASAAKI MUKAI AND RYOZO KOBAYASHI

Part 2: Video signal processing circuit

ASIAN AND PACIFIC SKILL DEVELOPMENT PROGRAMME
INTERNATIONAL LABOUR OFFICE
ISLAMABAD, PAKISTAN, 1988

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Contents

Part 2: Video signal processing circuit 1
The tuner 1
Video intermediate frequency (VIF) amplifier circuit 22
Video-detector circuit 34
AGC circuit 39
Video-amplifier circuit 43

Part 2: Video signal processing circuit

This chapter deals with the functional details of the circuits from the tuner to the video amplifier circuit inclusive.

The tuner

Structure and function

The tuner consists of three sections: the input, the RF amplifier and the converter (mixer and oscillator). (See Figure 2-1.) The tuning circuit of the RF amplifier in the tuner tunes to the RF signal of the desired TV station. The RF TV signal of the desired station is amplified by the RF amplifier, and processed into a video IF (VIF) signal by the converter circuit.

The VIF signal is coupled to the VIF amplifier circuit for further amplification. The tuner should satisfy the following characteristics for a good image reproduction on the screen.

Matching. For a good transmission of the RF signals received by the TV antenna to the receiver, the impedance of the feeder cable should be equal to or match the input impedance of the receiver at the antenna terminals. The procedure of setting these impedances equal is called *impedance matching*. The matching impedance for VHF is 300Ω.

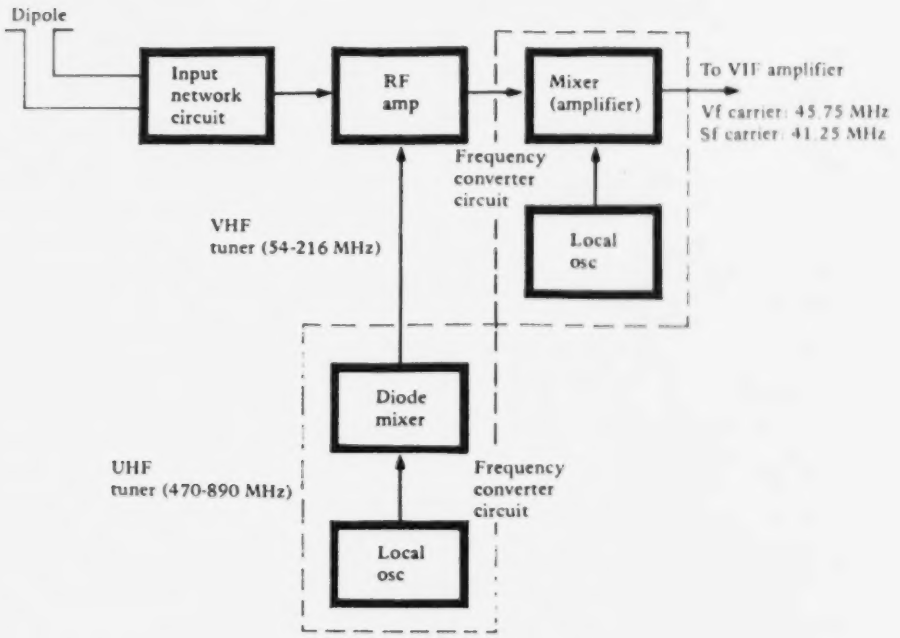


Figure 2-1
Block diagram of tuner circuit

Bandpass characteristic. For a good reproduction of a TV signal, the frequency response curve within the 6 MHz band of each channel should be as flat as possible. As shown in Figure 2-3, the variation in the gain of the tuner within the 6 MHz band of the RF signal is very little.

Noise figure (NF). Since the tuner circuit amplifies a very weak RF signal, the noise generated by the tuner circuit should be as small as possible. The noise figure (NF) gives the signal-to-noise ratio at the tuner input to the tuner output.

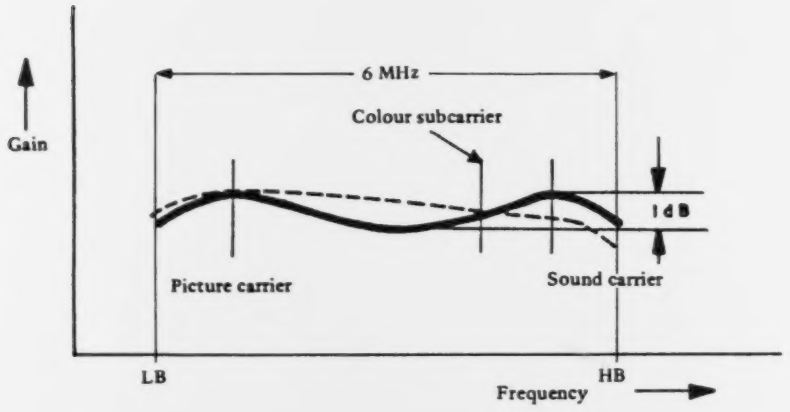


Figure 2-3
Tuner bandpass response

Cross-modulation and mutual-modulation. When the TV receiver is located in an area where the field strength of a TV station is very strong, the signal of this TV station is radiated or coupled directly to the VIF circuit.

This will interfere with the signal of the tuned-in station, resulting in an image with a beat distortion. This distortion is commonly called the "windshield-wiper" distortion.

Stability of the local oscillator. A drift in the local oscillator frequency will result in poor image reproduction, and RF signals of adjacent channels may interfere with the signal of the tuned-in station. The oscillator should have a stable design to minimise drift in the oscillation frequency.

An AFC (automatic frequency control) circuit is connected to the local oscillator to stabilise its oscillation. However, a drift in the oscillator frequency due to ageing cannot be avoided but this can be minimised by including the AFC circuit. In Figure 2-4 the drift in the oscillator frequency is plotted with respect to time. The drift is not too large, because the AFC circuit is included.

Local oscillator signal radiation does not result in interference in VHF reception, since the receiver's IF signal is selected such that the local oscillator frequency for any VHF channel is not included in the frequency band of any VHF channel.

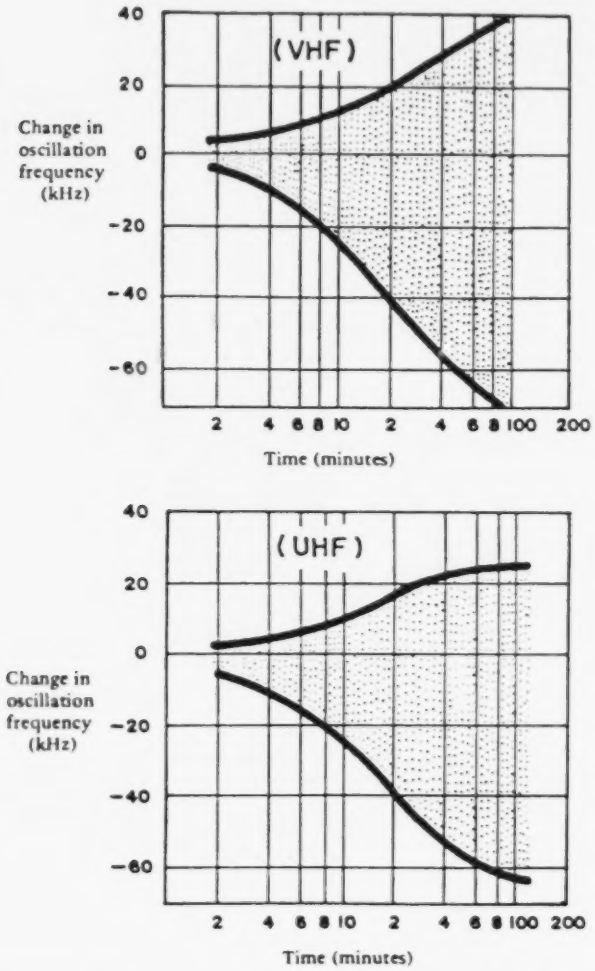


Figure 2-4
Drift in local oscillator frequency

Input circuit

The function of the input circuit is to match the input impedance of the receiver at the antenna terminals and the impedance of the feeder line. It also converts a balanced (300-ohm feeder cable) coupling to an unbalanced coupling (75 ohms, the input impedance of an RF circuit).

Two types of coupling circuits are commonly used in TV receivers. They are 1) the M-coupling circuit, which is used in UHF tuners, and 2) the balanced-coupling circuit, which is used in VHF tuners.

The balanced-coupling circuit uses a transformer called "balun."

Feedthrough bypass capacitors are generally used for bypassing the B+ and AGC lines into the RF tuner. L2 is a coaxial cable with one-half or one-fourth length acting as parallel coils in resonance with capacitor C1.

M-coupling. M-coupling is similar to an ordinary transformer coupling in which the signals are electromagnetically coupled.

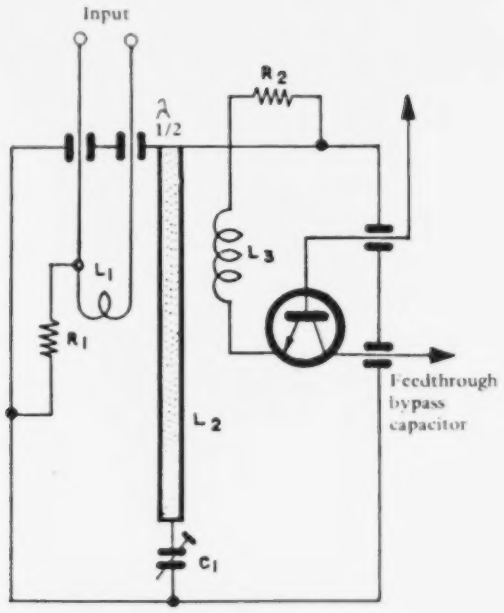


Figure 2-5
M-coupling input circuit (UHF)

The secondary winding of the transformer corresponds to the input tuning circuit of the RF amplifier stage. Figure 2-5 shows an example of an M-coupling circuit in a UHF tuner.

Balanced, or balun transformer, coupling. There are two kinds of feeder cables that can be used to transmit the TV signals from the antenna to the receiver. One is the ordinary balanced 300-ohm ribbon cable, the other is the unbalanced 75-ohm coaxial cable.

To match the input impedance of the TV receiver to the impedance of the two kinds of feeder cables, use a matching transformer with a very low conversion loss. This matching transformer is called "balun." An example of a balun unit is shown in Figure 2-6. (Balun stands for "balanced unit.")

RF amplifier section

The gain of the RF amplifier should be constant within its 6 MHz bandwidth. The circuit is designed to have a high gain to compensate for the noise generated by the mixer circuit. However, the RF amplifier should have a sharp response and a high attenuation outside its bandwidth.

The RF amplifier acts as a buffer to prevent the local oscillator-generated frequency from being transmitted out of the antenna. It may interfere with nearby TV receivers.

The RF amplifier consists of an input filter, an antenna tuning circuit and an RF amplifier transistor.

Input filter. The input filter is a high-pass filter (HPF) that blocks interfering signals with frequencies close to the VIF frequency of the receiver. (IF trap is 40-47 MHz.) Input filters trap FM frequencies 88-108 MHz to prevent the FM

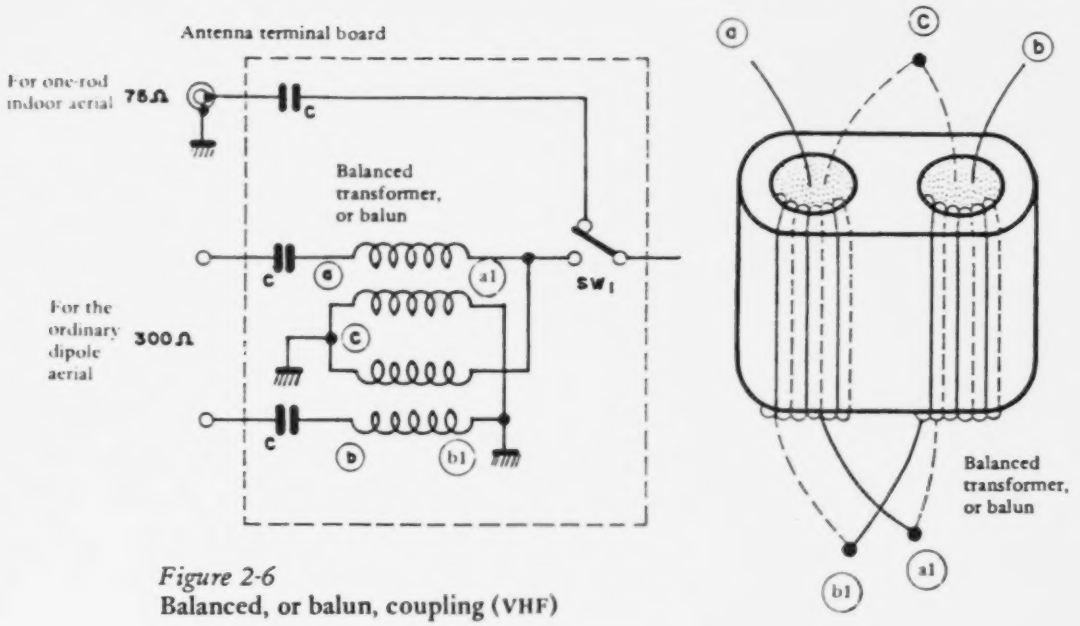


Figure 2-6
Balanced, or balun, coupling (VHF)

frequencies from interfering with the RF signal. This filter also protects the RF amplifier circuit from lightning and static charges from the external antenna. Figure 2-8 shows an example of an input-filter circuit.

Antenna tuning circuit. 1) VHF. Figure 2-9 shows an example of an antenna tuning circuit for the VHF tuner. The tuning circuit is formed by coils L_{CH} and L1 and by capacitors C4 and C5.

L_{CH} is channel-dependent and is replaced by other coils when the receiver is tuned to other channels. C4 is shorted when the receiver is tuned to the low VHF bands.

2) UHF. Because of the high frequencies in the UHF bands, it is impractical to use a tuning circuit similar to the tuning circuit of the VHF tuner. Instead a resonant coaxial cable tuning circuit with the length of the coaxial cable either one half or one fourth of the wavelength of the resonant frequency is used.

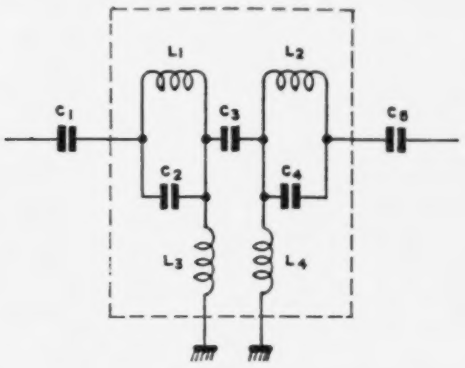


Figure 2-8
Input-filter circuit

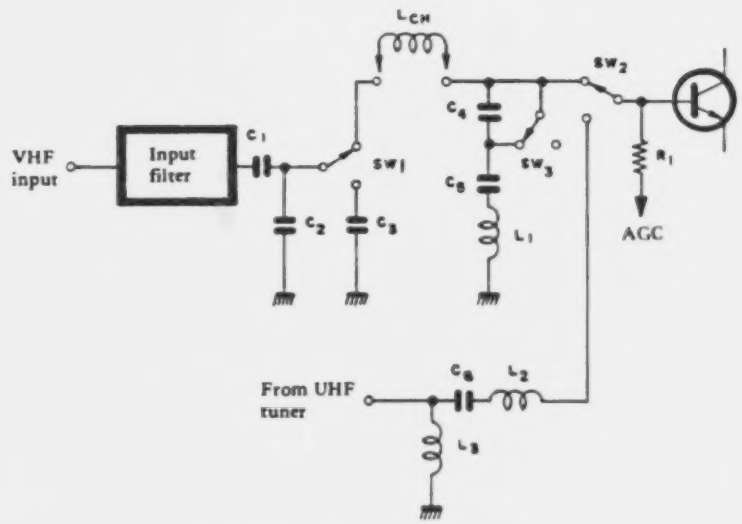


Figure 2-9
Antenna tuning circuit

When a one-fourth wavelength coaxial cable is shorted at one end, the impedance at the open end seen by resonant signals is infinite. This is similar to a parallel resonant circuit. The resonant frequency of the coaxial cable can be changed by varying its length.

It is more practical, however, to vary the resonant frequency by connecting a variable capacitor at the open end of the cable, as shown in Figure 2-10(a).

A similar parallel resonant circuit can also be made using a one-half wavelength resonant coaxial cable with both ends open, as shown in Figure 2-10(b). Similarly the resonant frequency of this resonant cable circuit can be varied by connecting a variable capacitor at one open end.

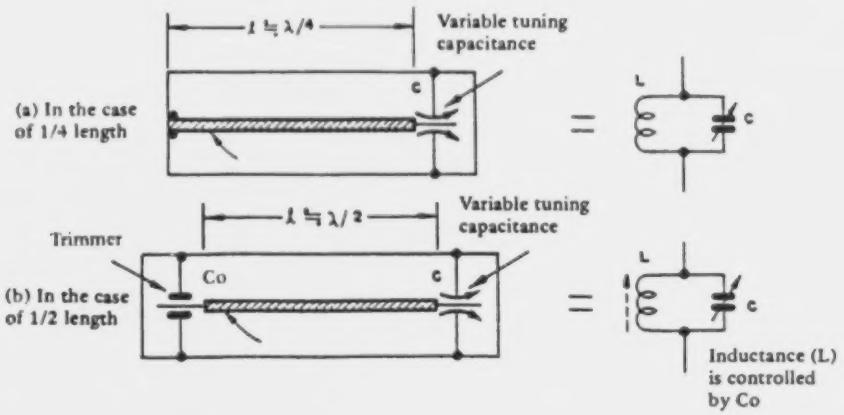


Figure 2-10
Coaxial resonance circuit

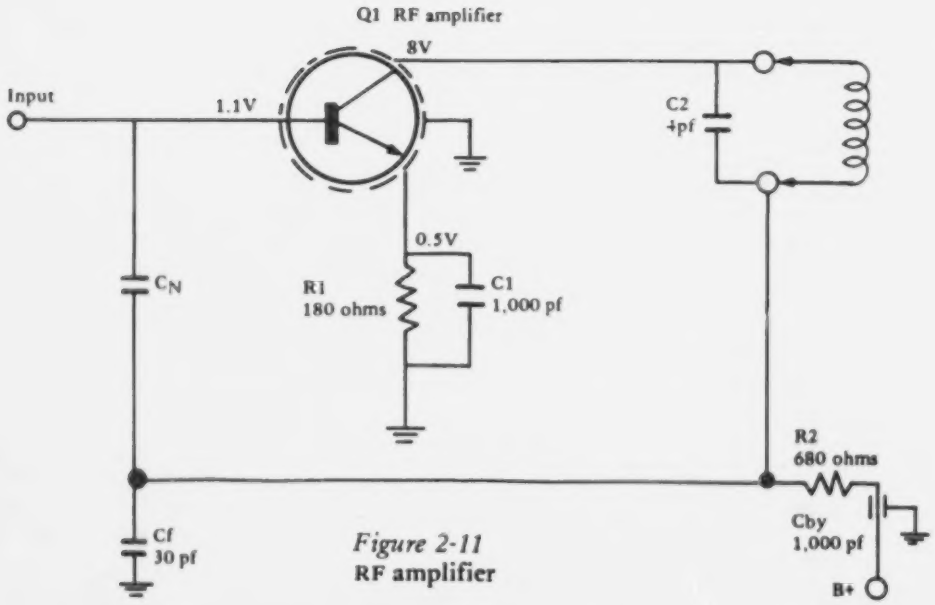


Figure 2-11
RF amplifier

RF amplifier stage. A common-emitter amplifier or a FET (field-effect transistor) amplifier is usually used in RF amplifier circuits.

In common-emitter amplifiers, part of the output signal serves as a positive feedback to the input due to the internal capacitance of the transistor. This feedback causes the RF amplifier to oscillate and have an unstable operation. To prevent this, as shown in Figure 2-11, a negative feedback signal is supplied to the input by Cn to counteract the effect of the positive feedback. This function is called "neutralisation" and it stabilises the function of the amplifier circuit and prevents oscillation.

Frequency converter section

The converter section of the tuner circuit converts the RF signal of the tuned-in TV station into a more stable VIF signal. The converter circuit consists of a mixer and the local oscillator stage.

Mixer circuit. The mixer circuit beats the RF signal and the local oscillator signal to produce a stable VIF signal for the VIF amplifier circuits. Figure 2-12(a) shows an example of a mixer circuit.

The frequency of the VIF signal is equal to the difference between the local oscillator frequency and the RF frequency.

The RF signal and the local oscillator signal are coupled by C1 and C3, respectively, to the base of transistor Q. The local oscillator signal is heterodyned with the RF signal to produce a VIF signal. The VIF output signal is taken out from the collector circuit. The efficiency of the mixer circuit depends on its conversion gain.

A diode is used as a mixer in UHF tuners. The conversion gain of a diode mixer is lower than the gain of a transistor mixer. Thus the VHF tuner is designed to operate as a VIF amplifier for the UHF VIF signals during UHF reception to boost the strength of the UHF VIF signals.

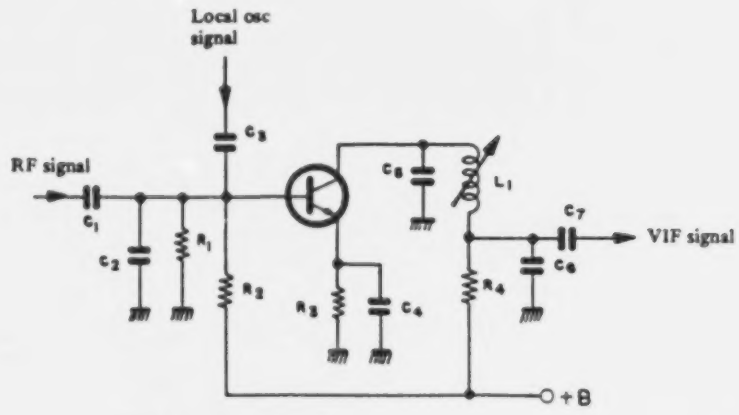


Figure 2-12(a)
VHF mixer circuit

Local oscillator circuit. The Colpitts oscillator circuit is commonly used in the local oscillator circuit because of its simplicity and stability. An example of a Colpitts oscillator circuit is shown in Figure 2-13.

Another basic oscillator circuit commonly used in the local oscillator is shown in Figure 2-14. This circuit, a modified Colpitts oscillator, is called a Krapp oscillator. It has a higher stability than the Colpitts oscillator.

A drift in the local oscillator frequency results in windshield-wiper distortion and poor image reproduction. To stabilise the oscillation of the local oscillator, special attention must be paid to the designing of the circuit and to the selection of the components.

Components that compensate each other's change in characteristic due to heat and drift in the power-supply voltage are used.

An actual VHF local oscillator circuit is shown in Figure 2-15(a). L1 is replaced whenever the channel selector is switched to another channel to enable the oscillator to vary at a unique frequency for each channel.

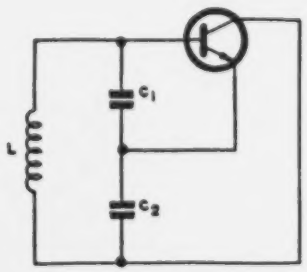


Figure 2-13
Basic Colpitts oscillator circuit

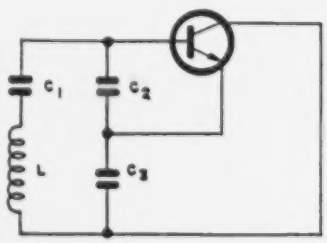


Figure 2-14
Modified Colpitts oscillator circuit (Krapp oscillator circuit)

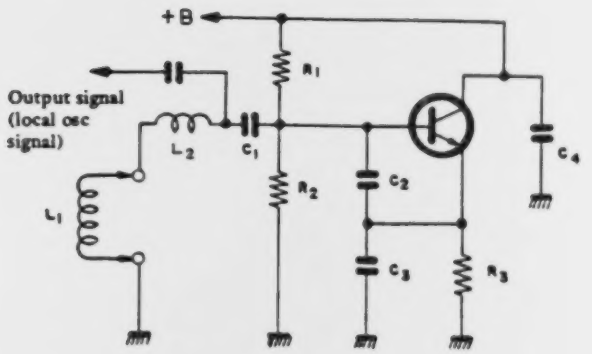


Figure 2-15(a)
A VHF local oscillator circuit

Channel selection

The frequency allocation of TV stations in the United States, for example, is divided into: the VHF low-band channels 2-6 (54-88 MHz), the VHF high-band channels 7-13 (174-216 MHz), and the UHF channels 14-18 (470-890 MHz).

In the Japanese TV broadcasting band, the VHF band is assigned to 90-108 MHz and 170-222 MHz; the UHF band, 470-770 MHz.

VHF tuner. Channel selection in conventional TV receivers is done by switching the coils in the tuner through a channel selector switch.

There are four types of VHF tuners: 1) turret, 2) rotary, 3) disk turret and 4) electronic.

A turret tuner is shown in Figure 2-16(a). Each individual channel has an independent set of coils mounted on one strip. Thus, individual channel adjustment for maximum tuning and coupling is possible.

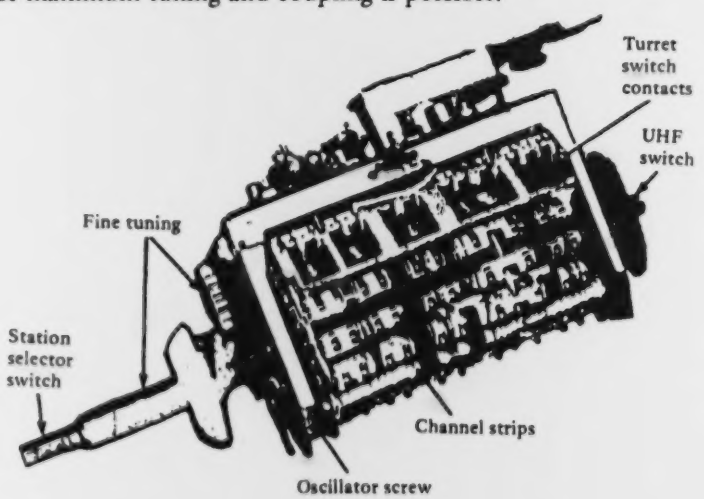


Figure 2-16(a)
Turret tuner with coil strips for each channel shield cover off

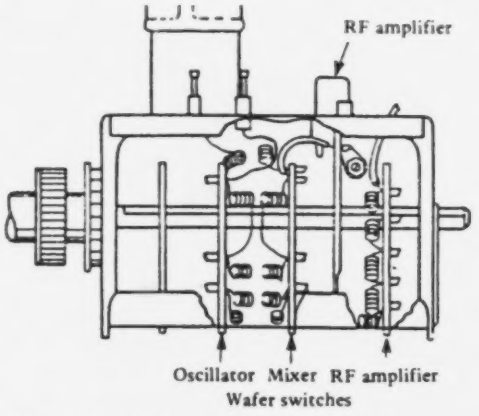


Figure 2-16(b)
Rotary-switch tuner with wafer switches for each stage

A rotary tuner is shown in Figure 2-16(b). It has rotary wafers for the tuned stages of the tuner. In every wafer the coils of the different channels are connected in series; hence individual channel adjustment is not possible.

A disk turret tuner is shown in Figure 2-16(b). This tuner arrangement is similar to the rotary tuner. The oscillator coils, mixer coils and RF amplifier coils are all mounted on their respective wafers. Unlike in the rotary tuner, however, the coils on each wafer are independent of each other. Thus individual channel adjustment is possible.

UHF tuner. Since there are so many channels in the UHF band, it is not practical to use a channel selector similar to the VHF channel selector due to the complication that will result in its design and structure.

Thus a linear tuning system, similar to the tuning system in ordinary radio receivers, is used. A TV set is tuned to different UHF stations by adjusting a variable capacitor. To facilitate convenience in tuning, a mechanical detent is provided in the tuner for each channel.

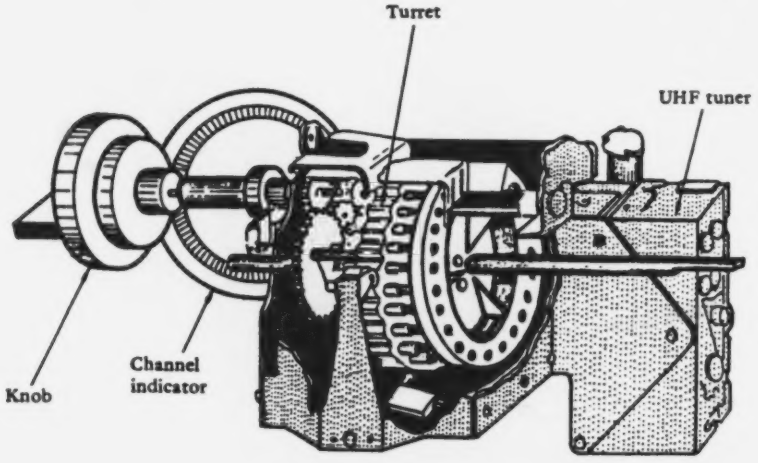


Figure 2-17
A UHF tuner

Figure 2-17 shows a UHF tuner. It has a pre-set mechanism that can tune the receiver to the desired UHF channel. By simply setting the selector to the desired UHF channel, just like in VHF channel selectors, the pre-set mechanism automatically tunes the receiver to the desired channel.

UHF and VHF tuner coupling. Modern TV sets usually have VHF and UHF tuners. As described before, the VHF tuner is used as a part of a VIF amplifier circuit when the set is tuned in to a UHF station.

When the VHF selector is set to the UHF position, signals from the VHF antenna are automatically grounded, the local oscillator of the VHF tuner is disabled and proper coils are set in the VHF tuner to tune the VHF RF amplifier to the VIF frequencies. The VIF signal from the UHF tuner output is coupled to the input circuit of the VHF RF amplifier.

AFT circuit

The local oscillator is designed to oscillate at a unique frequency for every channel to produce the correct VIF signal (45.75 MHz picture carrier) for the VIF circuits.

However, a drift in the oscillator frequency is unavoidable due to the heat and ageing of the oscillator circuit.

To avoid excessive drift, a fine tuning circuit and an AFT (automatic fine-tuning) circuit are connected to the oscillator circuit.

The local oscillator can be fine-tuned by varying the value of an inductor or a capacitor in the circuit.

In practical applications, a brass conductor is inserted inside the coil and the inductance is varied. However, periodic fine-tuning adjustments, each time the set is tuned to another station, are tiresome.

The AFT or the ALFC (automatic local-oscillator frequency control) relieves us from the burden of constantly adjusting the fine-tuning circuit.

Figure 2-18 shows a functional block diagram of an AFT circuit. A drift in the local oscillator is detected by the circuit enclosed by the dashed lines.

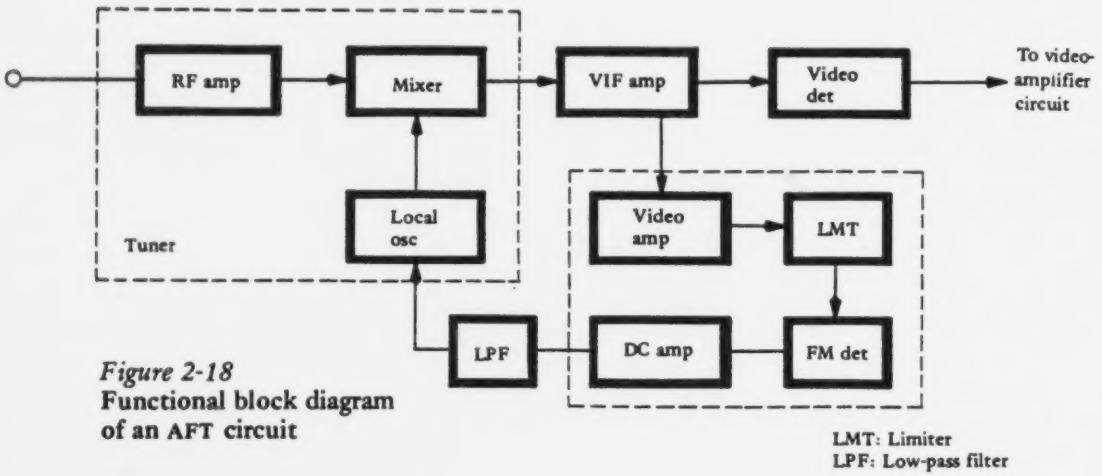


Figure 2-18
Functional block diagram of an AFT circuit

When a drift is detected in the local oscillator frequency, the AFT circuit sends a DC-control voltage proportional to the drift to a variable capacitor (varicap) diode in the oscillator.

The control voltage varies the capacitance of the varicap to restore the local oscillator to its original frequency.

The general details in the function of the AFT circuit shown in Figure 2-19 are enumerated below:

1 The VIF signal (45.75 MHz) is tapped from the VIF amplifier circuit and then amplified.

2 Amplitude variations in the VIF signal are clipped by a limiter circuit to produce a continuous wave (CW) VIF carrier signal.

3 The VIF carrier signal is detected by an FM detector, and drifts in the IF carrier signal from the correct IF frequency are reflected as changes in the output level of the FM detector.

4 The FM detector output is amplified and supplied as a control voltage to the varicap in the local oscillator circuit through a low-pass circuit.

The static capacitance of the varicap is inversely proportional to the reverse-bias voltage across its terminals. It is the variable static capacitance of the varicap which is controlled to compensate the frequency drifts in the local oscillator signal.

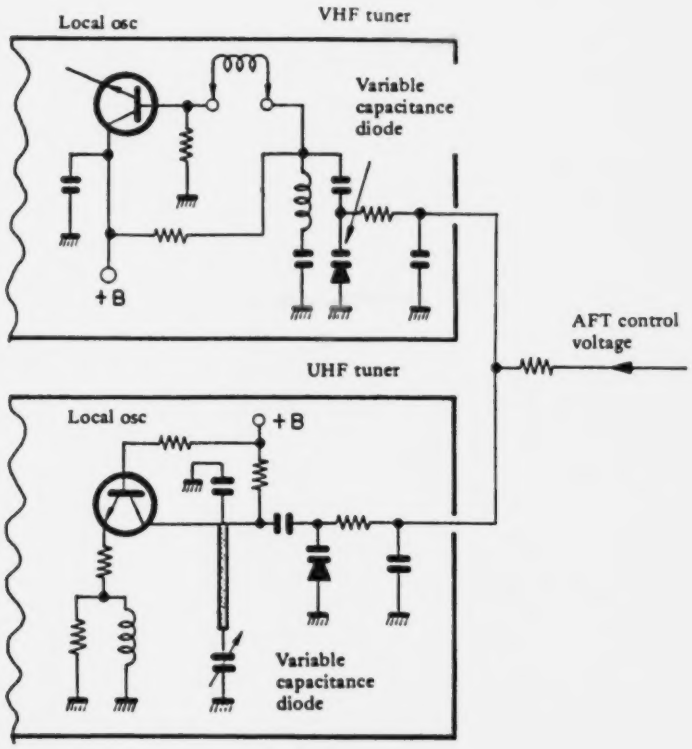


Figure 2-19
Supply of AFT voltage to the tuner circuit

Figure 2-21 shows an AFT circuit commonly used to control the local oscillator circuit.

The electronic tuner

An electronic tuner uses a variable capacitance (varicap) diode for its tuning circuit. Channel selection is done electronically, unlike in conventional tuners where tuning is done mechanically.

The electronic tuner is tuned to different TV stations by changing the DC reverse-bias voltage across the varicap diode.

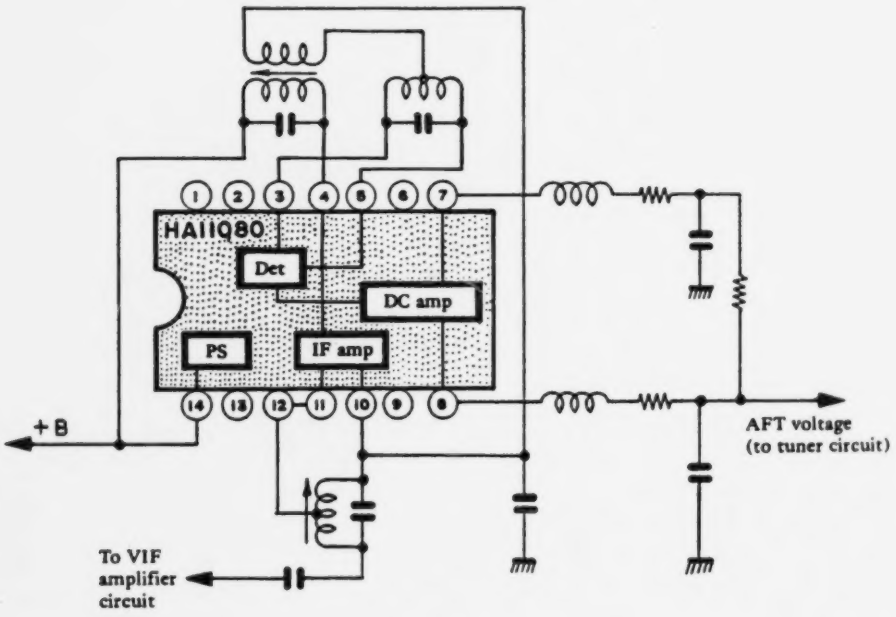


Figure 2-21
An IC AFT circuit

This type of tuner is favourable compared with its conventional counterpart. It has no moving mechanical components, and eliminates mechanical problems such as loose contact.

Electronic tuning principle. A basic electronic tuning circuit is shown in Figure 2-22. The tuner is tuned to various channels by switches SW1 to SW5. Each switch represents a TV station.

When a switch is closed, a corresponding DC voltage for the station represented by the switch is supplied to the varicap diode. The supplied voltage can be adjusted and set (programmed) to a certain value by the variable resistors R3 to R7.

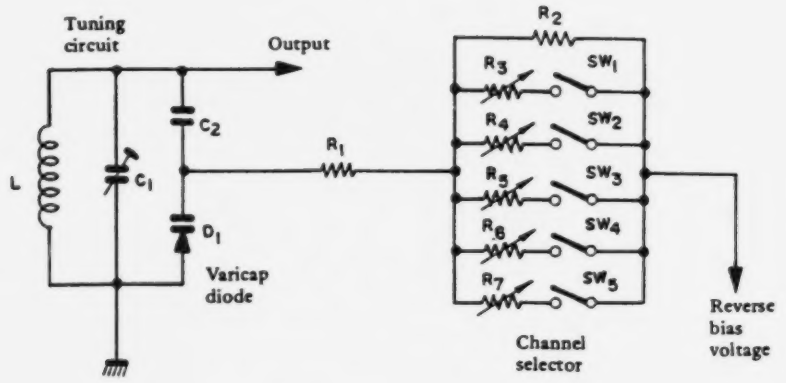


Figure 2-22
A basic electronic tuning circuit by varicap diode

The electronic VHF tuner. The variation in the capacitance of the varicap is limited, so its operation is confined over a limited band of frequencies. Because of this limitation, the varicap cannot be tuned to the entire channels of the VHF band.

Thus the tuning circuit in an electronic tuner is divided into two sections. One section is designed to tune to the low-band channels (2 to 6), the other to the high-band channels (7 to 13).

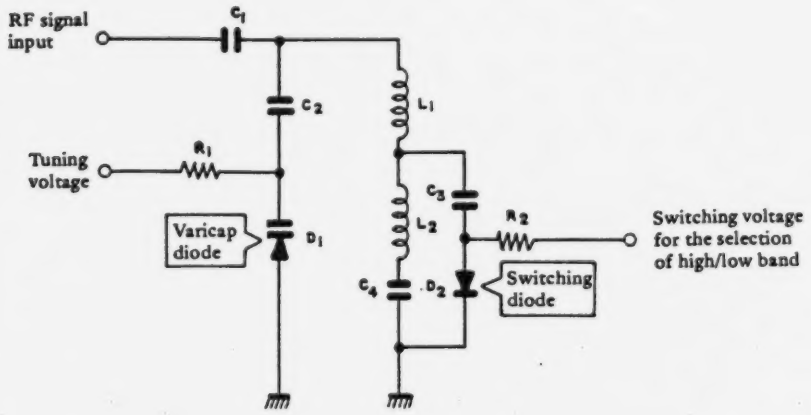


Figure 2-23
A VHF tuning circuit

Figure 2-23 shows a tuning circuit in an electronic VHF tuner.

D2 switches the tuner to the low- and high-band channels. When D2 is not forward-biased, it acts as an open switch, forming the tuning circuit for the low VHF bands.

When D2 is forward-biased, the diode acts as a closed switch, forming the tuning circuit for the high VHF bands.

Figure 2-24 shows a local oscillator circuit in an electronic VHF tuner. D1 switches the local oscillator from the low- to the high-band channels and vice versa.

Figure 2-25 shows a frequency-control circuit for a VHF electronic tuner.

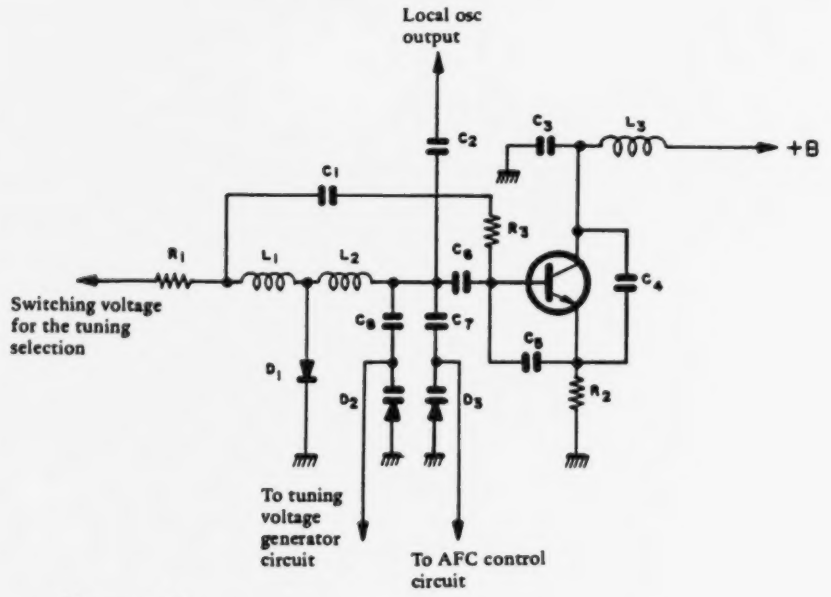


Figure 2-24
A local oscillator circuit

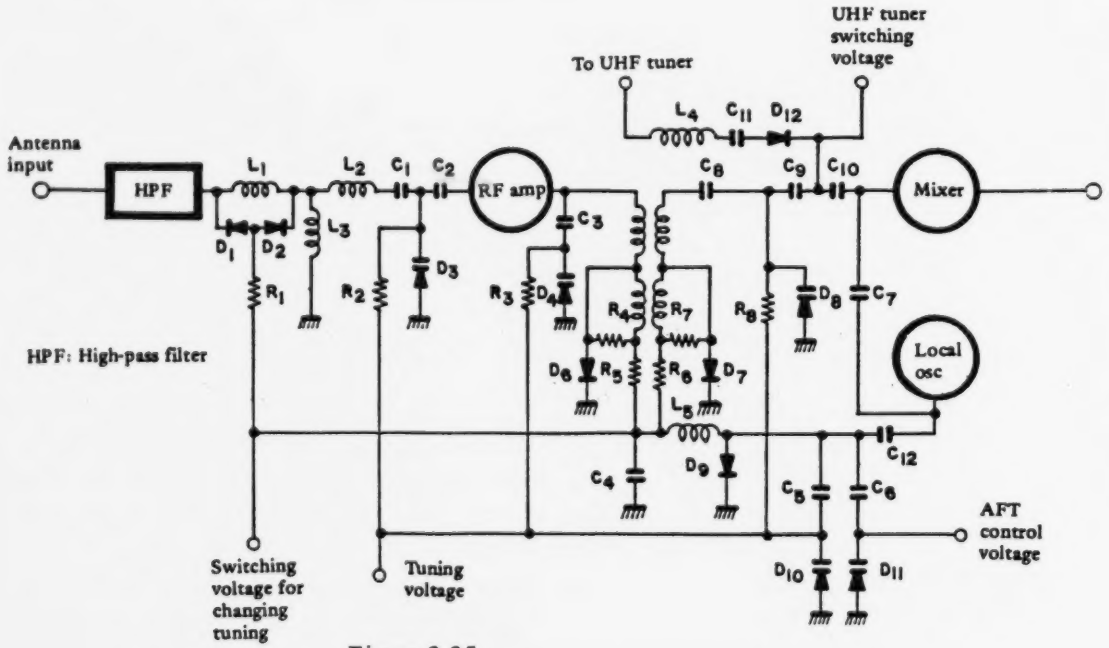


Figure 2-25
Control voltage in a VHF electronic tuner

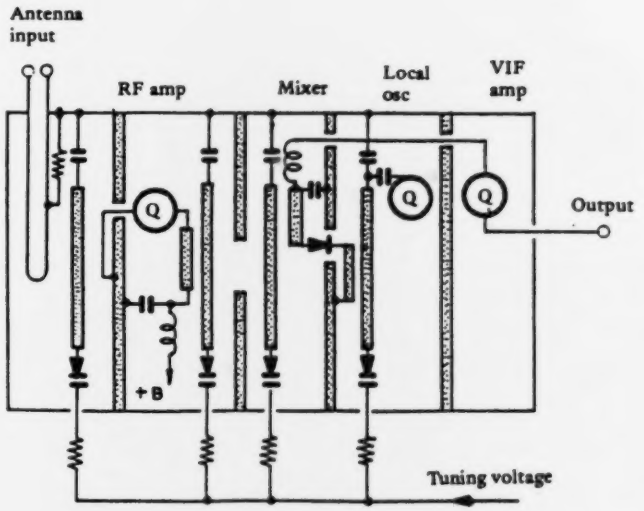


Figure 2-26
Electronic UHF tuner

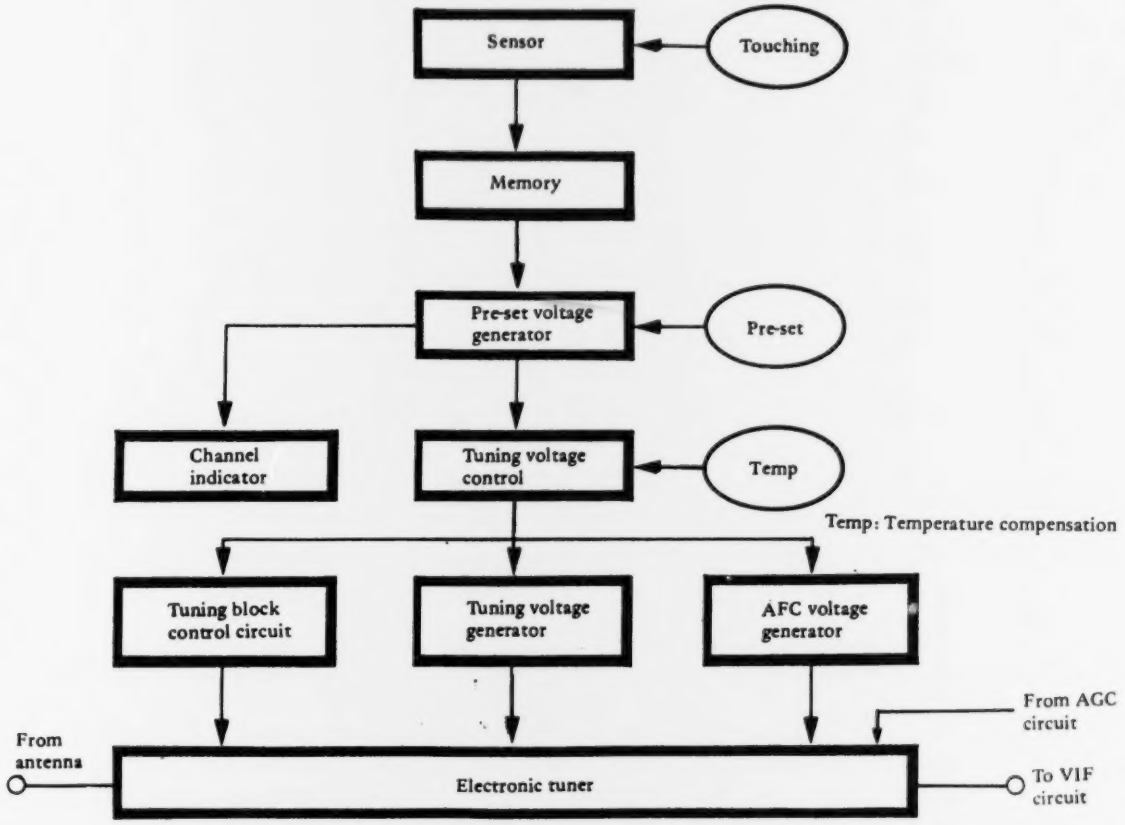
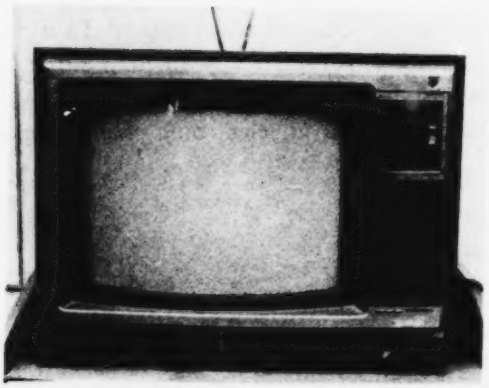


Figure 2-27
Functional block diagram of an electronic channel selector



Picture 2-4
A push-button receiver front-end panel

The electronic UHF tuner. The electronic UHF tuner shown in Figure 2-26 similarly uses a varicap diode for its tuning circuit. The varicap is connected in series to the open end of the coaxial cable resonant circuit.

The circuit is tuned to a particular channel by supplying the proper DC reverse-bias voltage to the varicap.

A disadvantage in electronic UHF tuners is the considerable tuning loss due to the small internal resistance of the varicap diode. Hence an RF amplifier is included in UHF tuners to amplify further the output of its tuning circuit.

Channel selector circuit. Push-button switches are used for channel selection in an electronic tuner.

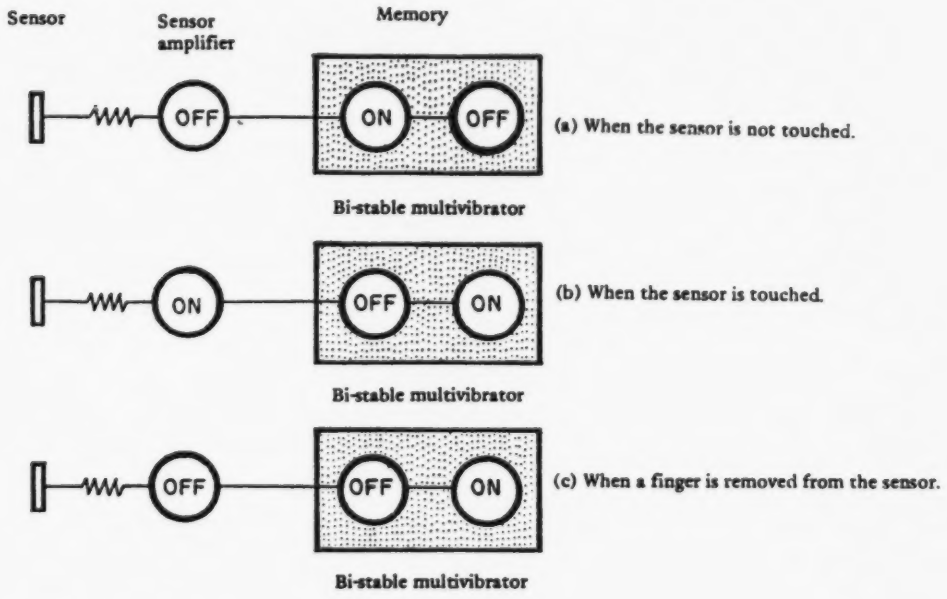


Figure 2-28
Function of a touch amplifier and a memory circuit

The DC voltages for every TV channel are initialised. Thus, by simply pressing the proper switch, the tuner is automatically tuned to the desired TV station.

Picture 2-4 shows a push-button receiver front-end panel.

A functional block diagram of an electronic channel selector circuit is shown in Figure 2-27.

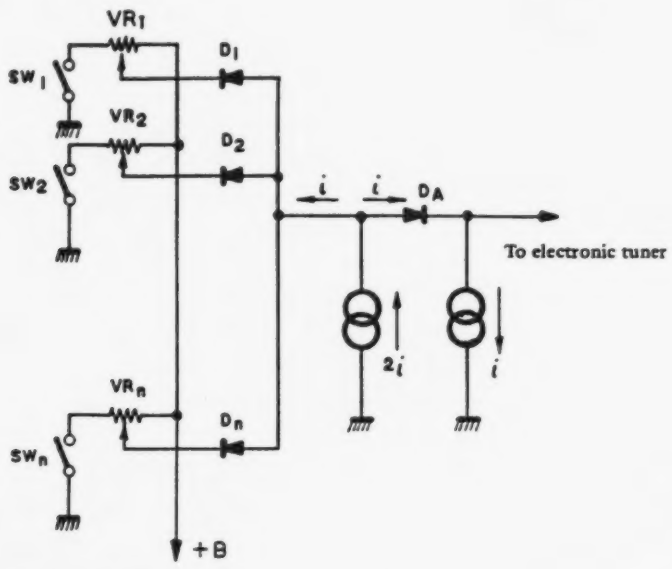


Figure 2-29
Tuning voltage generator circuit

Touch amplifier and memory circuits

A touch amplifier circuit senses current flow from the human body when the sensor in the channel selector panel is touched. It amplifies the current flow in our bodies to activate a memory circuit.

The circuit usually makes use of a bi-stable multivibrator circuit or the difference between the ON-OFF voltage of a neon tube. Figure 2-28 shows how a touch amplifier and a memory circuit function.

Tuning voltage generator circuit

Figure 2-29 shows a simple tuning voltage generator circuit.

Switches SW1 to SWn are the equivalent memory circuits. Variable resistors VR1 to VRn are registers assigned to each switch for pre-setting or programming the voltages of every TV station.

When the sensor of the memory circuit represented by SW1 is touched, SW1 closes. Initially, before SW1 closes, the cathode voltage of D1 is equal to the B+ voltage. When SW1 closes, a voltage drop is developed across VR1. Consequently, the cathode voltage of D1 decreases. VR1 is set such that D1 is forward-biased when SW1 is closed. When D1 is forward-biased, the anode voltage becomes equal to the cathode voltage (actually, plus the junction voltage but this is negligible), which is pre-programmed by VR1.

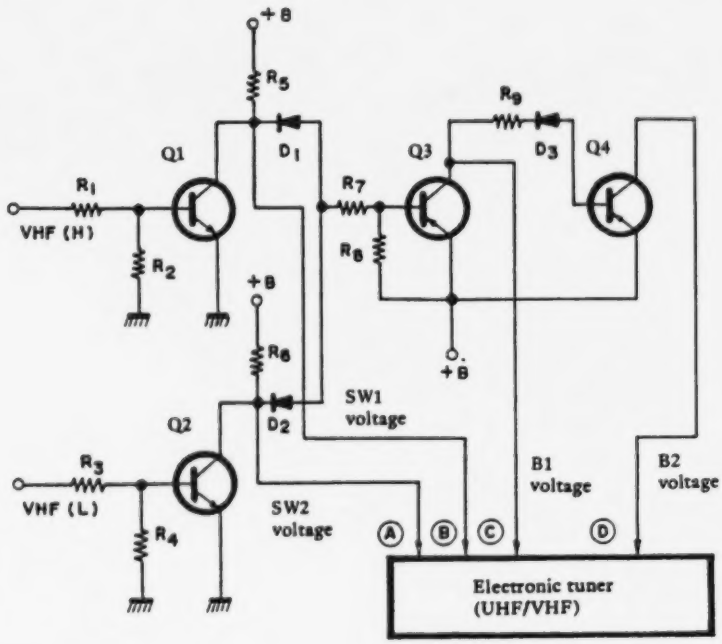


Figure 2-30
Tuning block switching circuit

Switching circuit for VHF and UHF bands

Figure 2-30 shows a switching circuit used in switching an electronic tuner from the VHF to the UHF bands and vice versa. The transistors function as switches.

For the high VHF bands, the memory circuit supplies a positive voltage to the base of Q1. This turns on Q1, and the voltage at terminal (B) of the electronic tuner becomes approximately zero. In this case, D1 is forward-biased and Q3 is turned on. So the B+ voltage is supplied to terminal (C).

On the other hand, D3 is reverse-biased and Q4 is cut off, leaving terminal (D) floating. Q2 is also cut off, so the B+ voltage is also supplied to terminal (A).

For the low VHF bands, the memory circuit supplies a positive voltage to the base of Q2. This turns on Q2, and terminals (A) and (D) become approximately equal to zero volts. Furthermore, Q3 is ON and Q1 is OFF, so the voltages at terminals (B) and (C) are equal to the B+ voltage.

For the UHF bands, Q1 and Q2 are cut off, so the B+ voltage is supplied to terminals (A) and (B).

Q3 is also cut off, so terminal (C) is floating and Q4 is switched on, so the B+ voltage is supplied to terminal (D).

To sum up: the electronic tuner can be switched to the VHF and UHF bands by supplying control voltage to Q1 and Q2. By doing so, the voltages at terminals (A), (B), (C) and (D) are set to the proper voltage combinations

to switch the tuner to the desired TV broadcast band.

AFT control voltage

The electronic tuner is affected if the AFT signal voltage is supplied to it during the channel selection. Thus one must disable the AFT circuit during the selection.

Methods of disabling the AFT circuit

There are three ways to disable the AFT circuit during the channel selection. These are by: a) using the pulses generated before the glow of a neon tube used for the channel indicator; b) using the pulses tapped from the sensor amplifier or memory circuit; and c) setting the tuning voltage to a low value to decrease the local oscillator frequency.

Remote-control apparatus

The ultrasonic and the infrared frequencies are used for remote-control purposes.

Ultrasonic remote controls. The frequency of the ultrasound used for remote-control purposes ranges from 30 to 50 kHz. Every remote-control function is assigned to different frequencies.

A special kind of ultrasound is used to avoid interference with the electronic tuner. An electronic oscillator is generally used in generating ultrasounds for remote control.

Infrared remote controls. A light-emitting diode is used to transmit infrared signals from the control box. A photo-diode in the TV set receives the infrared signal and converts it to a control signal.

Examples of actual tuner circuits

Figure 2-31 shows an actual TV tuner circuit. The VHF tuner is a disk-turret type and the UHF tuner has also its own RF amplifier.

In a VHF mode, RF signals from the antenna are coupled to the input tuning circuit. The tuning circuit passes the RF signal of the tuned-in station and rejects the rest. The desired RF signal is then fed to the RF amplifier circuit. L8 and L9 electromagnetically couple the amplified RF signal to the mixer circuit.

C16 couples the local oscillator signal to the mixer circuit, where the RF signal and the oscillator signal are heterodyned. The output of the mixer circuit is the VIF signal. The VIF signal is coupled to the succeeding VIF circuits.

In a UHF mode, the RF signal is fed to the mixer diode (D51) after being amplified by the UHF RF amplifier. The VIF signal at the output of the UHF mixer is supplied to the VHF tuner through a coaxial cable. The mixer and the RF amplifier of the VHF tuner amplifies the VIF signals from the UHF tuner to boost its strength before it is coupled to the VIF circuits.

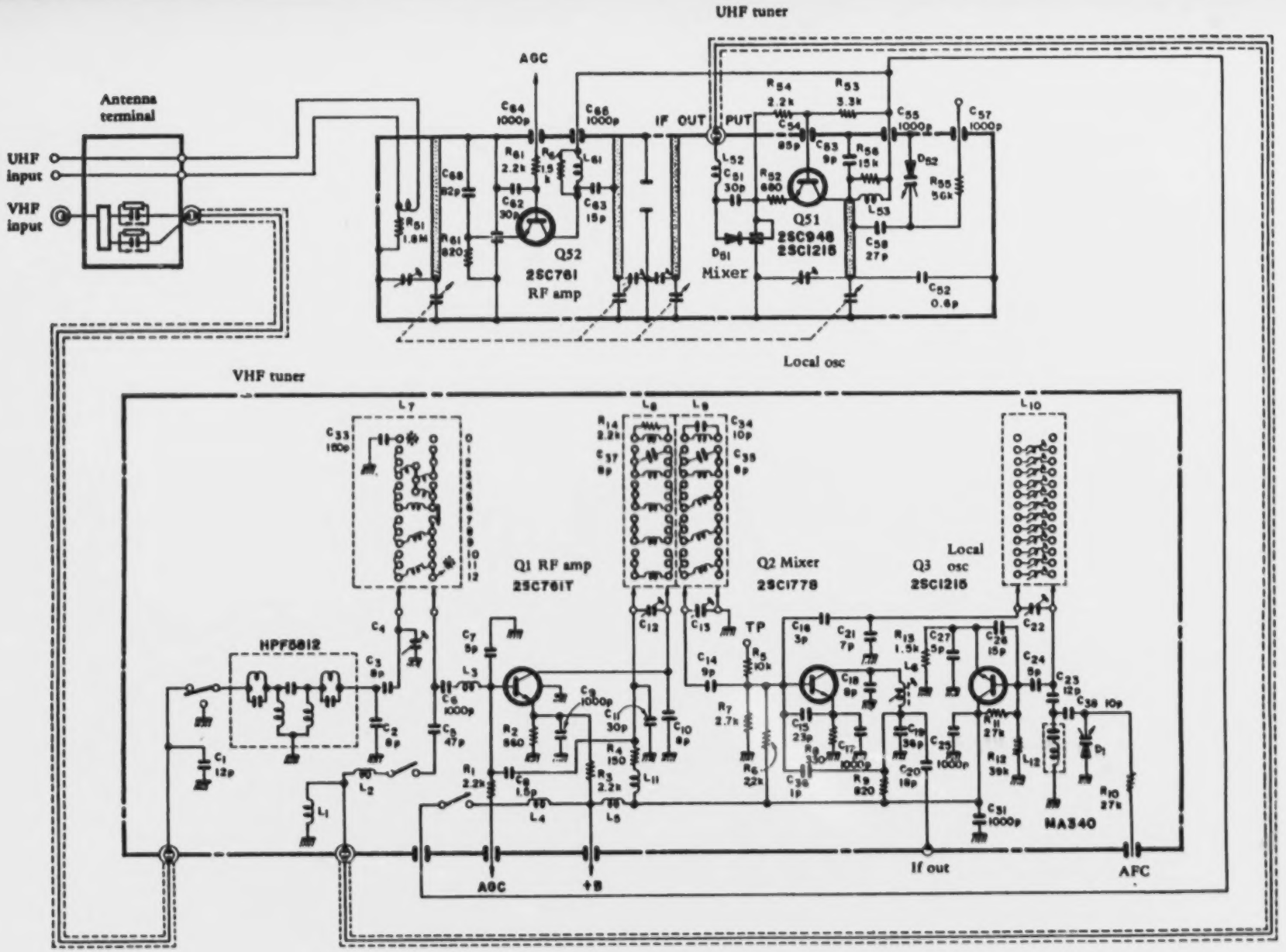


Figure 2-31
An actual tuner circuit

Video intermediate frequency (VIF) amplifier circuit

Structure and function of the VIF amplifier circuit

The VIF amplifier circuit supplies most of the gain of the whole block of the video signal reproduction circuit.

The quality of the picture reproduced on the screen is directly affected by the selectivity of the VIF amplifier circuit.

As shown in Figure 2-32(a), the vestigial sideband transmission is used in sending the TV RF signal.

If the VIF amplifier circuit is designed to have a flat frequency response within the band of the VIF signal like the tuner [Figure 2-32(e)], the VIF amplifier circuit should be designed to have the frequency response shown in Figure 2-32(d).

Thus, in the design of the VIF amplifier circuit, a special selectivity response is to be considered for vestigial sideband transmitted signals.

Intermediate frequency (IF)

The frequency for the IF signal in TV receivers is chosen to avoid possible interference with other circuits such as the local oscillator circuit.

Receivers made in the Philippines and in the USA use the IF band 41-47 MHz. In Japan the IF signal is in the 50 MHz band.

The local oscillator frequency for each TV station is chosen to be higher than the RF signal carrier frequency.

Thus the order of the video and sound carriers in the IF signal is reverse compared with the order of the video and sound carriers in the RF signal.

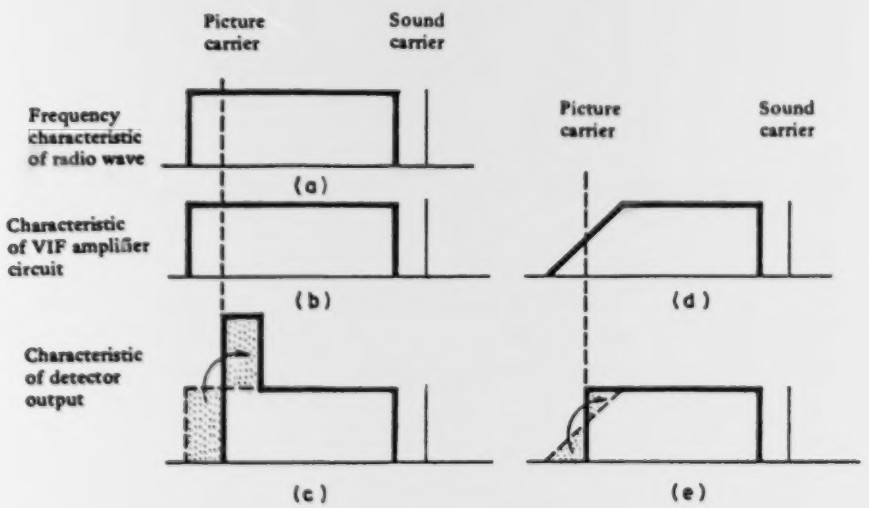


Figure 2-32
Relationship between the selectivity of a TV receiver and the frequency response of the detector output

The video carrier in the IF signal is 45.75 MHz and the sound carrier is 41.25 MHz for receivers made in the Philippines and in the USA. The video and sound carriers are 58.75 MHz and 54.25 MHz in Japan.

The AGC bias is usually applied to the first IF stage because the gain can be controlled since the signal is still low. The three VIF stages are stagger-tuned to cover the 4 MHz bandwidth.

Selectivity response of the VIF circuit

Although the selectivity response of a TV receiver is determined by the total selectivity of the tuner and VIF circuits, the overall response of a TV receiver is more dependent on the response of the VIF circuit.

The VIF amplifier should have a bandwidth of 4 MHz (video bandwidth).

However, if the VIF circuit is designed to have this bandwidth, the sidebands corresponding to the low video frequencies of the picture signal of the upper adjacent channel and the sound signal of the lower adjacent channel can interfere with the picture signal of the desired station. This interference causes the windshield-wiper effect.

Considering vestigial sideband transmission, interference is avoided by designing a VIF amplifier with a selectivity response shown in Figure 2-33.

To avoid the windshield-wiper effect, the sound carrier of the lower adjacent channel and the picture carrier of the upper adjacent channel is attenuated.

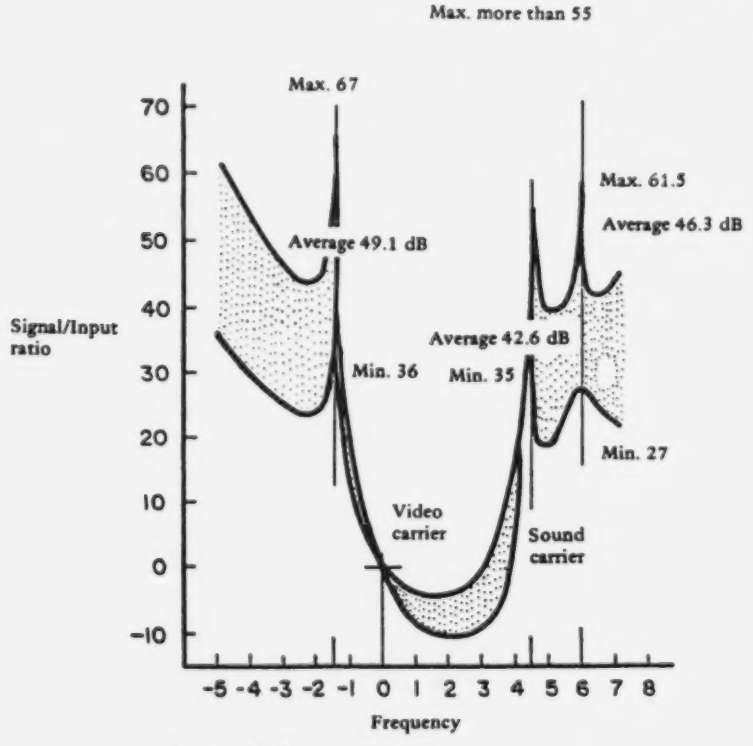


Figure 2-33
Selectivity of a VIF amplifier circuit

The colour subcarrier signal (3.58 MHz) is located at the slope from the peak of the video carrier signal.

Thus, at the detector output, the level of the colour subcarrier signal is uneven.

This distortion is compensated by the special transformer in the input circuit of the bandpass amplifier circuit.

VIF amplifier circuit

The VIF amplifier circuit is usually formed by three to four tuned amplifier stages in order to get a 70 dB gain and the necessary bandwidth.

Figure 2-34 shows a variety of the tuning circuits used in the VIF amplifier circuit.

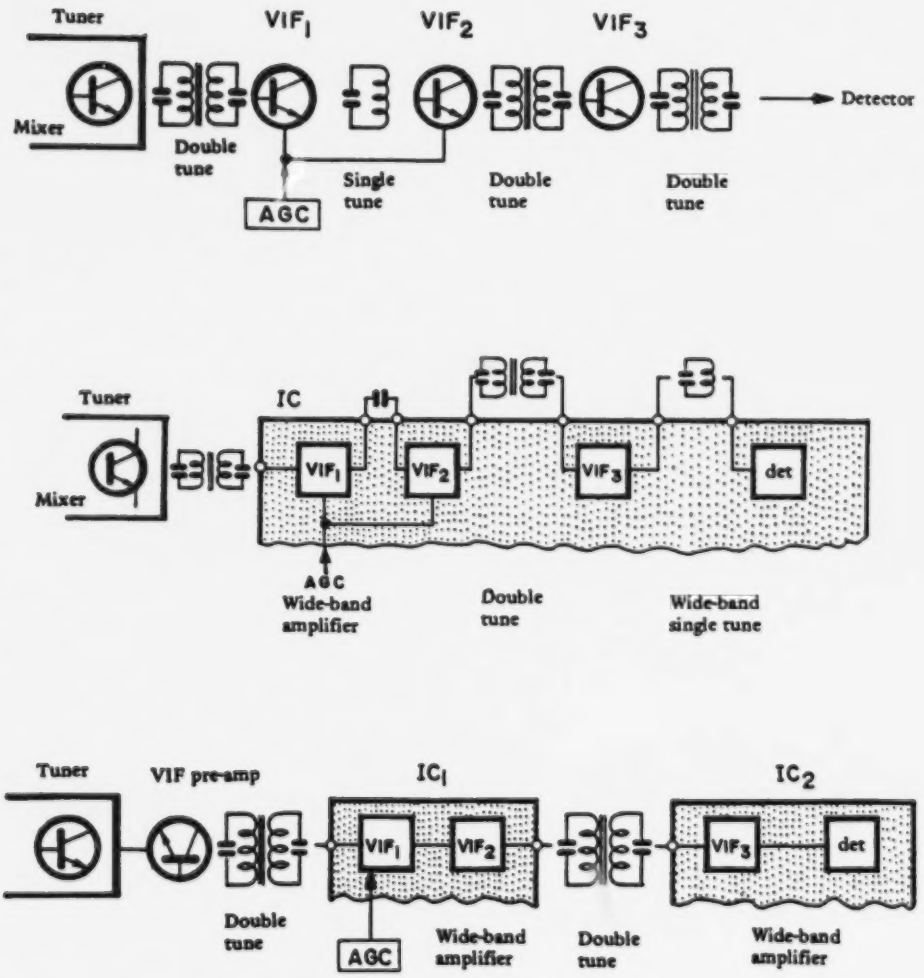


Figure 2-34
Various tuning circuits in a VIF amplifier circuit

The necessary bandwidth of the VIF circuit is obtained in solid-state receivers by using combinations of single- and double-tuned circuits.

The first stage is usually a wide-band single-tuned amplifier circuit.

For VIF amplifier IC circuits, the IC functions as the wide-band amplifier. The tuning circuit is placed at the input and the output of the IC circuit to get the required frequency response.

Single-tuned circuit. There are many types of single-tuned circuits, as shown in Figure 2-35.

The type used in the VIF circuit depends on the type of transistor or the type of amplifier circuit used in the VIF circuit.

The bandwidth of the VIF circuit depends on the quality factor Q of the tuning circuit used. The smaller the value of Q, the wider the bandwidth of the circuit.

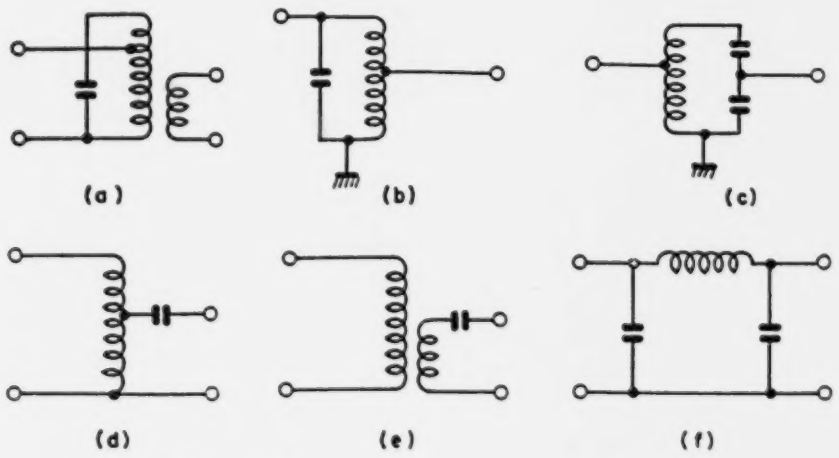


Figure 2-35
Single-tuned circuits

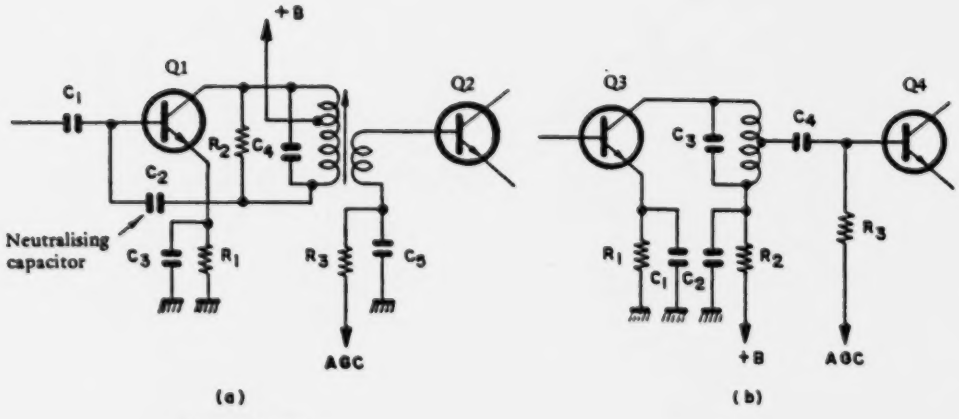


Figure 2-36
Examples of wide-band single-tuned amplifier circuits

Figure 2-36 shows examples of tuning circuits used by the ones shown in Figures 2-35(a) and (b). In these circuits the AGC voltage is applied to Q2 and Q4.

Double-tuned circuit. A double-tuned circuit has a sharper selectivity than a single-tuned circuit.

Figure 2-37 shows two types of double-tuned circuits commonly used. These circuits are inductance-coupled and capacitance-coupled.

The circuit in Figure 2-34 is used to get the ideal selectivity of the VIF circuit.

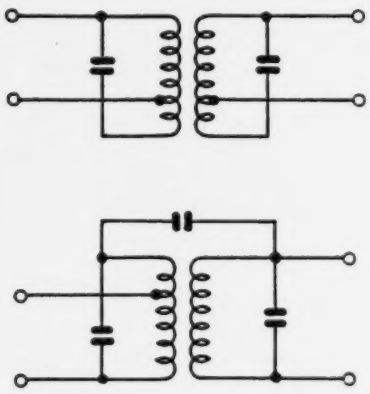


Figure 2-37
Double-tuned circuits

Figure 2-38 shows double-tuned amplifier circuits.

Figure 2-38(a) is a double-tuned circuit inductively coupled by T2.

Figure 2-38(b) shows another double-tuned circuit in which two single-tuned circuits (T1 and T2) are capacitively coupled by C6.

Trap circuit

Besides the methods of getting the proper selectivity for the VIF circuit described in the section on "Selectivity Response of the VIF Circuit," trap circuits are used to get sharper selectivities. The traps used in a VIF circuit are sound signal and adjacent channel signal traps.

Capacitance-coupled trap. Figure 2-39 shows the capacitance-coupled trap circuits. A trap circuit using a simple series resonance circuit is shown in (a). This trap is usually used in circuits having a rather low impedance. It is commonly used for sound and adjacent channel signal traps.

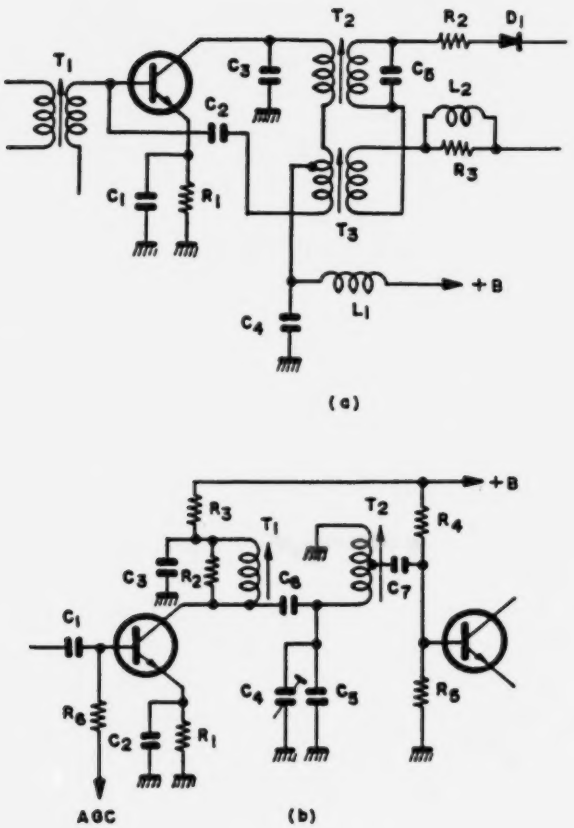


Figure 2-38
Double-tuned circuits

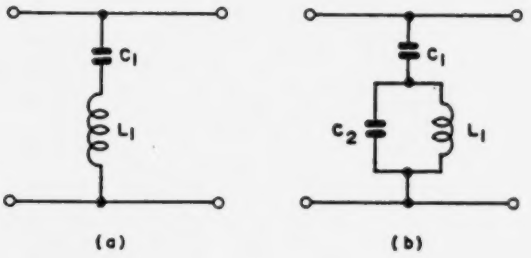


Figure 2-39
Capacitance-coupling traps

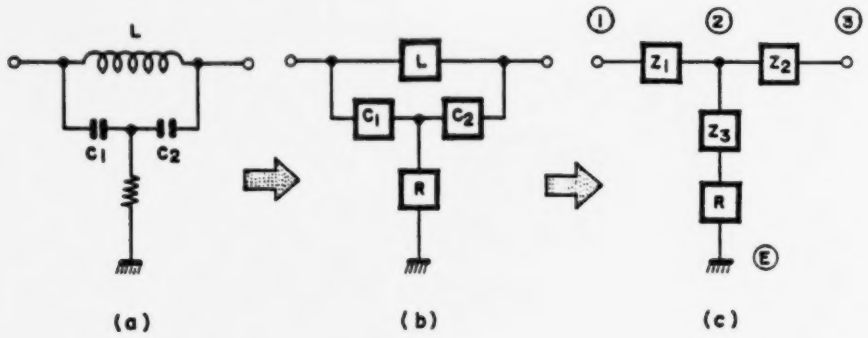


Figure 2-40
Bridge-trap circuit

The bridge trap. Figure 2-40(a) shows a bridge-trap circuit. The resonant frequency is determined by the values of L, C1 and C2. The circuit shown in (b) is a block representation of the circuit in (a).

Figure 2-40(c) is a further generalisation of a bridge-trap circuit. When R is set equal to the magnitude of Z3, the circuit between points (2) and (E) in (c) behaves as a short to resonant frequency signals. Thus theoretically, an infinite attenuation can be obtained for resonant signals.

The M-coupling bridge trap. The M-coupling trap is used between the last stage of the VIF amplifier circuit and the video detector, as shown in Figure 2-41.

A loose-coupled L4 and a tight-coupled L3 with respect to input signal are connected in series. But they are wound in directions to induce opposing voltages

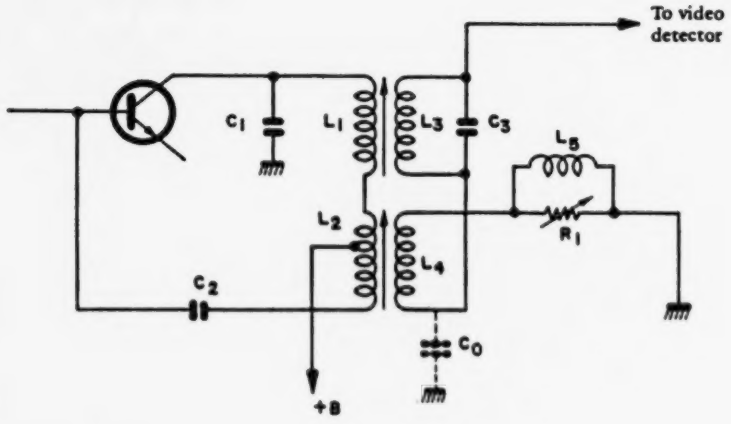


Figure 2-41
M-coupled bridge-trap circuit

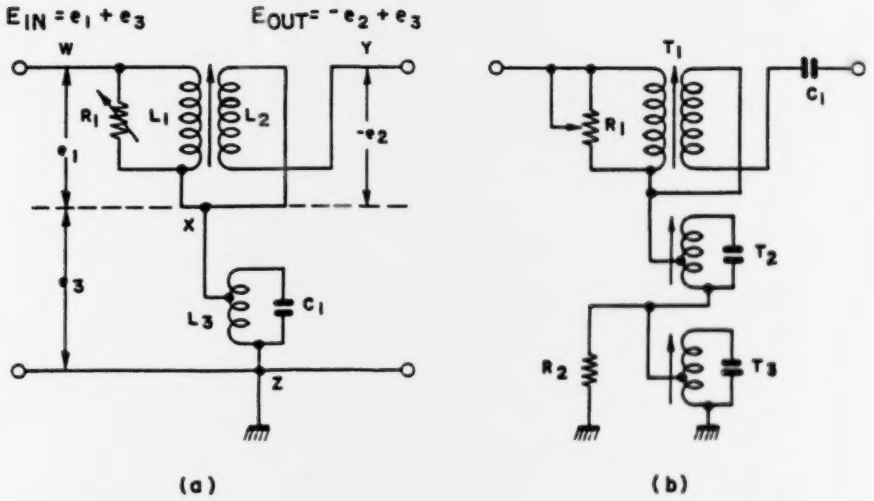


Figure 2-42
Bifiler T-trap circuit

The bifiler trap. Figure 2-42(a) shows the principle of a bifiler trap. Coils L1 and L2 are bifiler coils, thus having the same inductance. By setting the coupling factor to 1, e1 becomes equal to e2 (e1 = e2).

But as shown in the figure, by reversing the connection of L2, e1 becomes equal to - e2 (e1 = - e2). Connecting a parallel resonance circuit formed by L3 and C1, the circuit becomes inductive in lower frequencies. The equivalent inductance varies with the resonance frequency.

Figure (b) shows an application of the bifiler-trap circuit.

Transformers T1 and T2, T1 and T3 form pairs and function as adjacent channel-signal and sound-signal trap circuits respectively. A change in R1 is reflected to the two traps but mainly functions to adjust the sound-signal attenuation. The sound-signal attenuation is controlled because the sound signal is taken out from the succeeding stages.

Bifiler coils are transformers in which the primary and secondary are wound together. (See Figure 2-42(c).)

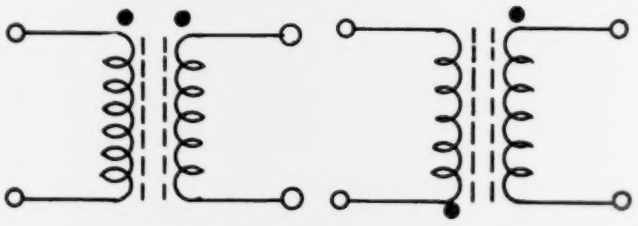


Figure 2-42(c)
Bifiler coils

Coupling circuit of tuner and video-amplifier circuit

The output of the tuner and the VIF amplifier circuit are linked by a coaxial cable. A coaxial cable, however, would be rather long, so a coupling circuit such as that shown in Figure 2-44 is generally used.

This coupling circuit uses a double-tuned capacitance-coupled circuit formed by C3, C4 and the static capacitance (Co) of the coaxial cable. With this coupling arrangement, the local oscillator signal which appears at the output of the mixer circuit will be blocked by the filter circuit formed by L1, C1 and C2.

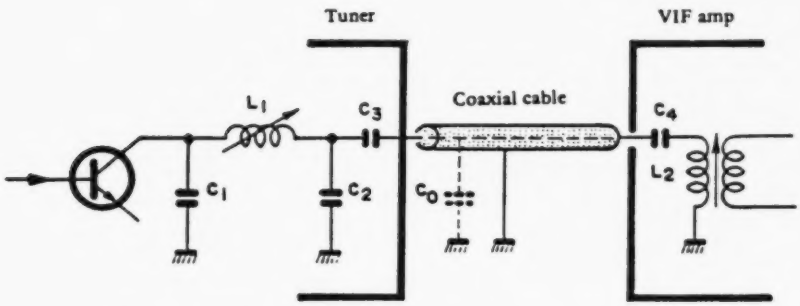


Figure 2-44
Coupling to a tuner circuit

Types of actual VIF circuit used in a TV receiver

VIF amplifier circuit in a solid-state TV. Figure 2-45 shows a three-stage transistorised VIF amplifier circuit.

The signal from the tuner is coupled to the circuit by a double-tuned circuit formed by T1 and T2 (IF transformers).

The coupled signal is then fed to the base circuit of Q1, where three traps are located. These traps are the lower-adjacent channel sound trap (47.25 MHz), sound trap (41.25 MHz) and the upper-adjacent channel sound trap (39.75 MHz).

Transistors Q1 and Q2 are coupled by a single-tuned circuit formed by T3; Q2 and Q3 are coupled by T4, which also is a single-tuned circuit.

The AGC control voltage which controls the gain of Q1 and Q2 is supplied to the base of Q2.

Q3 supplies the IF video signal to the video detector through T5, which is a double-tuned circuit.

Q3 should have a good linearity to prevent distorted signals coupled to the detector.

Note that the selectivity of the VIF amplifier circuit depends mainly on the selectivity of the double-tuned circuits formed by T1, T2 and T3, T4.

The 4.5 MHz sound signal is taken out from the primary of T3 and then supplied to the SIF amplifier circuit.

T2 is also a part of the M-coupled bridge-trap circuit, which traps the sound-signal carrier, preventing it from going to the input of the video detector.

VIF IC amplifier circuit. Figure 2-46 shows a typical VIF amplifier circuit consisting of ICs. In actual VIF amplifier circuits, ICs are used for wide-band amplification.

Tuning and trap circuits are placed at the input and output circuits of the ICs to meet the bandwidth requirement of the amplifier circuit, since inductive elements are difficult to include inside IC circuits.

The VIF signal from the tuner passes through the two bridge-trap circuits [the piezonator (X1) and the double-tuned circuit (T1)] before being fed to IC1.

The signal is amplified by the wide-band IC amplifier, whose gain is controlled by the AGC.

The amplified VIF signal is taken out from the tuning circuit formed by T2 and T3, with the overall frequency response adjusted.

This signal is further amplified by IC2 before being fed to the video-detector circuit.

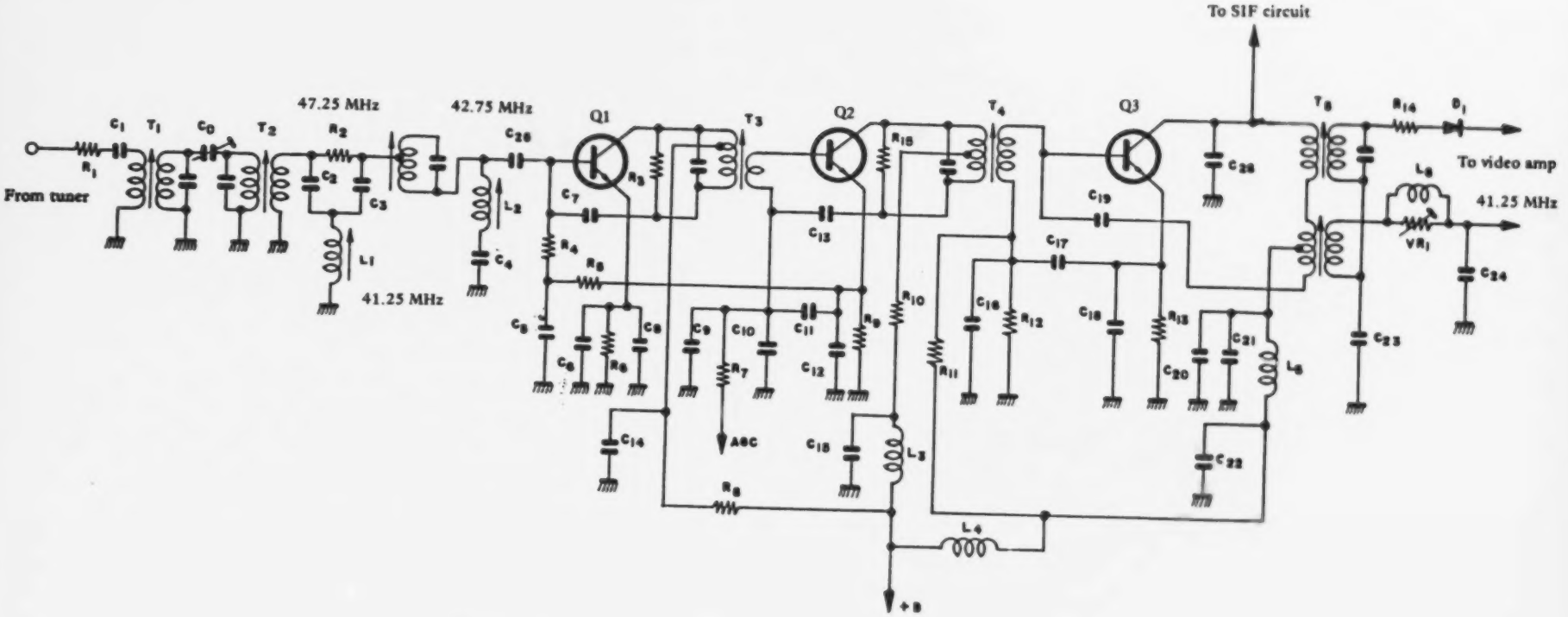


Figure 2-45
A VIF amplifier circuit

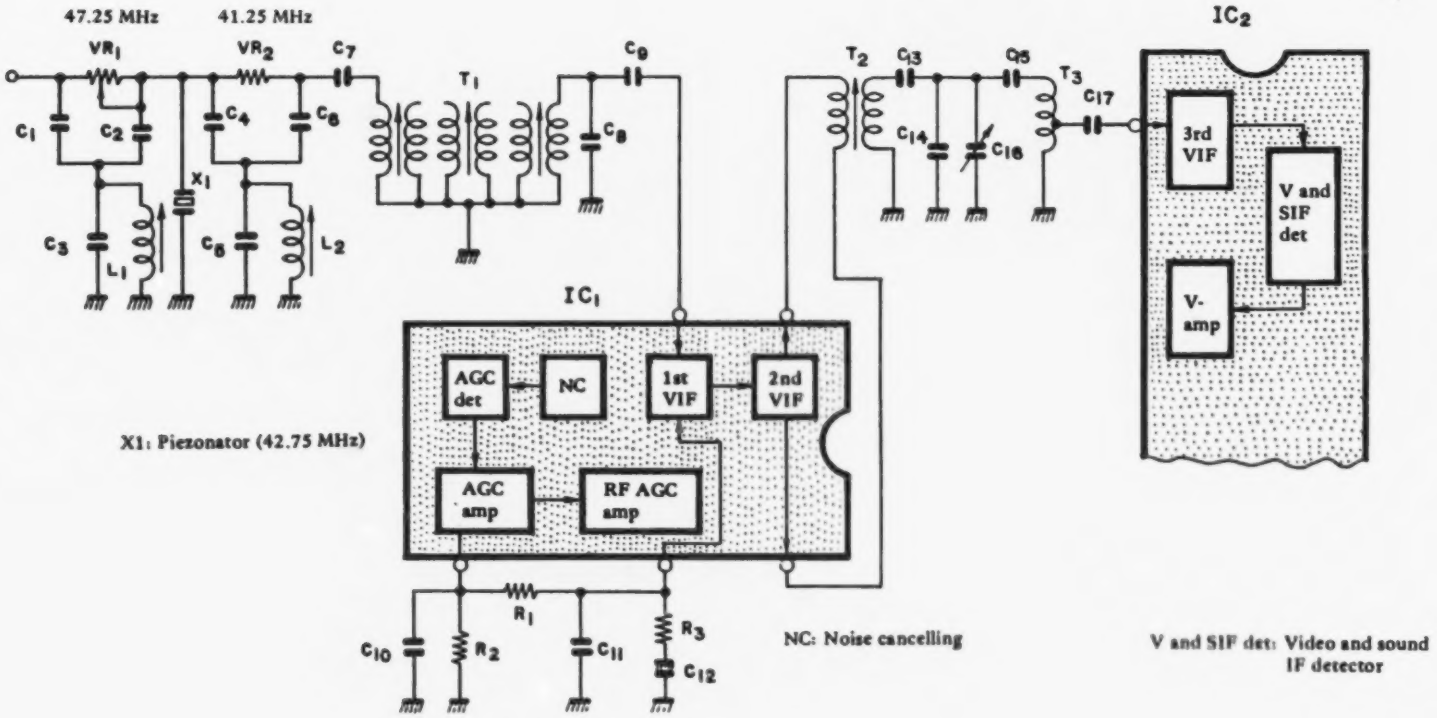


Figure 2-46
An IC VIF circuit

Video-detector circuit

The modulated TV IF signal amplified by the VIF amplifier circuit is detected by the video-detector circuit.

The output of the detector is the composite video signal.

To get a video signal with a low distortion and a high fidelity, a diode with a low distortion and good linearity or an LLD (low-level detector) circuit should be used for the video-detector circuit.

The load at the output of the video detector has a low-resistance resistor to provide a wider frequency response.

Video-detector diode circuit

The principle of a video-detector circuit using a diode will be explained, using the video-detector circuit shown in Figure 2-47.

The polarity of the composite video signal at the detector output depends on the orientation of the diode in the detector circuit.

A positive and negative polarity composite video signal is taken out in the circuits shown in Figure 2-47(a) and Figure 2-47(b) respectively.

The number of the stages used in the video amplifier circuit and the kind of drive used for the CRT (cathode- or grid-drive) determine the polarity of the video signal to be taken out from the output of the detector.

An example of a diode-detector circuit is shown in Figure 2-48.

The VIF amplifier output is coupled to the detector circuit by T1. Diode D1 detects the modulated signal, and a negative polarity composite video signal is taken out across R5.

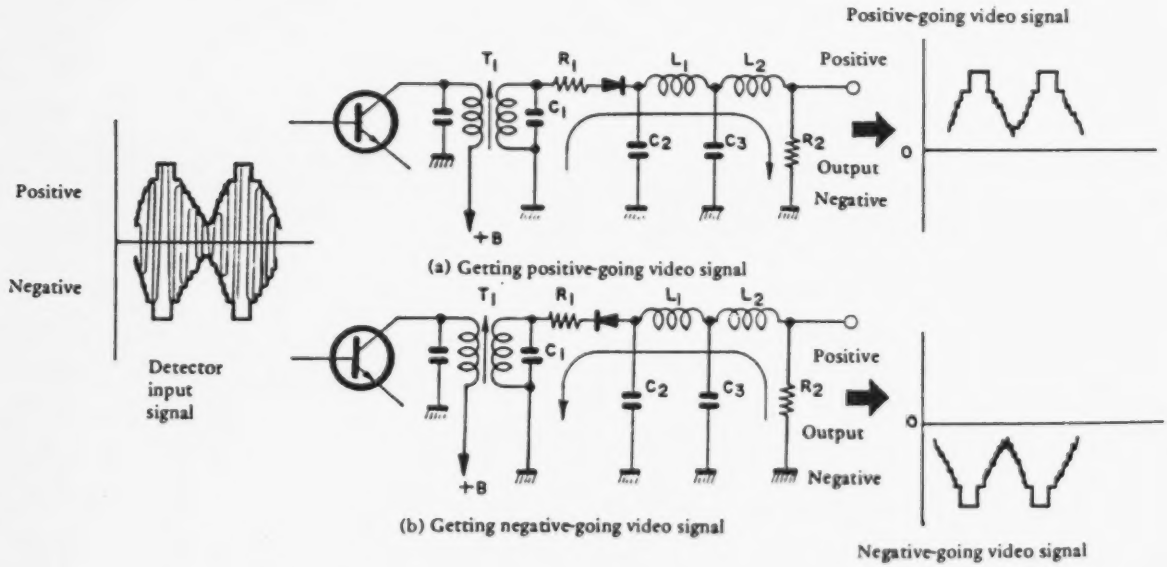


Figure 2-47
Video-detector circuit

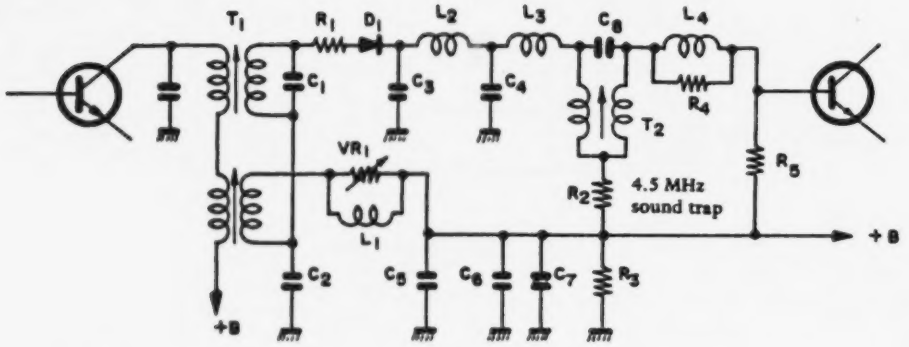


Figure 2-48
A diode video-detector circuit

The total parallel resistance consisting of R2 and R5 is the load resistance of the video detector. A small load resistance is connected to yield a wider frequency response.

Low-level video-detector circuit (LLD)

When an IC is used as a VIF amplifier, the use of an ordinary diode detector will decrease the quality of the picture. A different kind of detector circuit is needed.

An ordinary detector diode requires an input from 2 to 3 Vp-p to get an output with a good linearity and a low distortion.

This requirement arises from the non-linear characteristic of the input and output response curve of the diode around the cut-off or threshold point.

Because of the small gain in IC amplifier circuits, the output voltage of a VIF IC amplifier is not enough to drive the diode in the linear region to get a linear and a low distorted signal at the detector output.

Thus if an ordinary diode-detector circuit is used, a transistor amplifier circuit is needed to amplify the output of the VIF IC amplifier.

However, the addition of a transistor circuit in a VIF IC amplifier circuit complicates the design of the VIF circuit. So a different kind of video-detector circuit is needed to detect the VIF signal amplified by IC amplifiers.

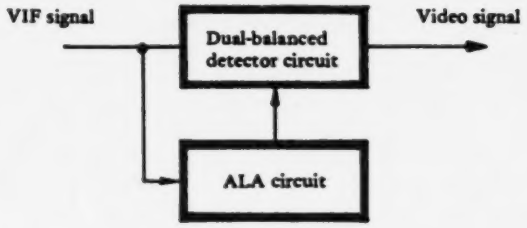
This circuit is the LLD (low-level detector) circuit, which yields a strong, linear and a low distorted output even if the strength of the input signal is weak.

Structure of an LLD circuit. Figure 2-49 shows a block diagram of an LLD circuit. It consists of an amplitude-limiter amplifier circuit and a dual-balanced detector circuit.

How the LLD circuit works. Figure 2-50 shows an LLD IC circuit.

Figure (a) shows the amplitude-limiter amplifier section. This circuit levels the amplitude of the video carrier signal.

Q10 and Q11 form a differential amplifier circuit. This circuit clips the amplitude variations in the IF signal, thus producing a 45.75 MHz signal carrier, and supplies this signal to the LC circuit.



ALA circuit: Amplitude-limiter amplifier circuit

Figure 2-49
Block diagram of an LLD circuit

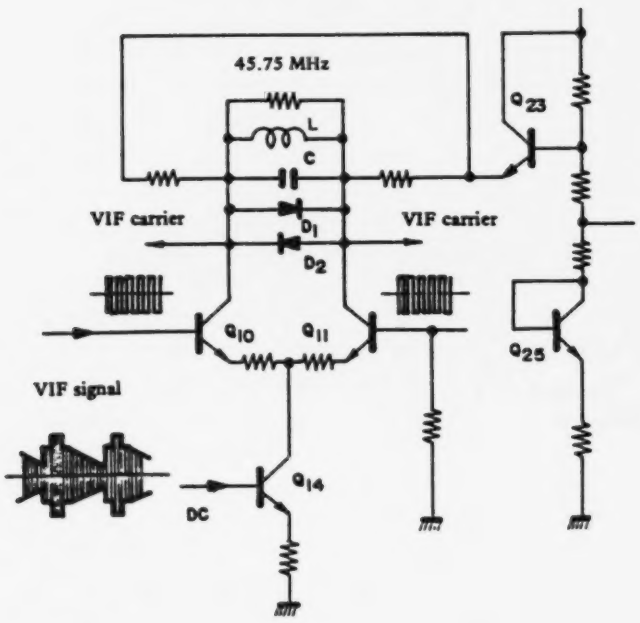


Figure 2-50(a)
Amplitude-limiter amplifier (ALA) circuit, an example of an LLD circuit

Diodes D1 and D2 clip the peak part of the carrier signal supplied to the LC circuit, thus producing a square wave.

Figure (b) shows a dual-balanced detector circuit.

The differential amplifier circuit formed by Q3 and Q6 amplifies the VIF signal fed to the base of Q3. The amplified signal is fed to the emitter circuits of the differential amplifiers Q1Q2 and Q4Q5.

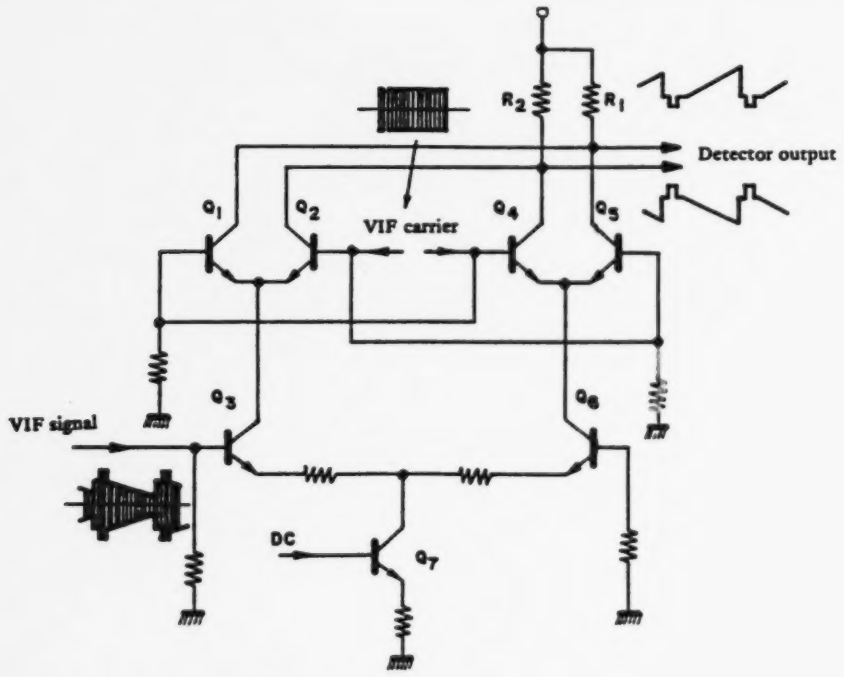


Figure 2-50(b)
Dual-balanced detector circuit, an example of an LLD circuit

On the other hand, the square-wave signal from the output of the amplitude-limiter amplifier is supplied to the base-circuits of the differential amplifiers Q1Q2 and Q4Q5. This signal switches on the two differential amplifiers alternately.

When the signal shown in Figure 2-51(a) is supplied to the emitter circuit of Q1Q2 and the signal shown in Figure 2-51(b) is supplied to the base of Q1, the signal shown in Figure 2-51(c) is then produced at the collector of Q1.

On the other hand, when the signals shown in Figures 2-51(d) and (e) are supplied to the emitter circuit of Q4Q5 and to the base of Q5, respectively, the signal shown in Figure 2-51(f) will be produced at the collector of Q5.

Therefore the signals shown in (c) and (f) are generated at alternate half-cycles across R1.

The signal shown in Figure (g) is the composite signal, consisting of the signals shown in (c) and (f), generated across the output resistor R1. The polarity of the video signal at the output is positive.

The signals produced at the collector of Q2 and Q4 are just the negative of the signals produced at the collector of Q1 and Q2, respectively. Thus a negative composite video signal is generated across R2.

In short, the VIF signal from the VIF IC amplifier output is amplified first by the differential amplifier Q3Q6, then detected by the two differential amplifiers Q1Q2 and Q4Q5.

Thus, even if the input IF signal is weak, a strong composite video signal with good linearity and low distortion can be taken across the output of an LLD circuit.

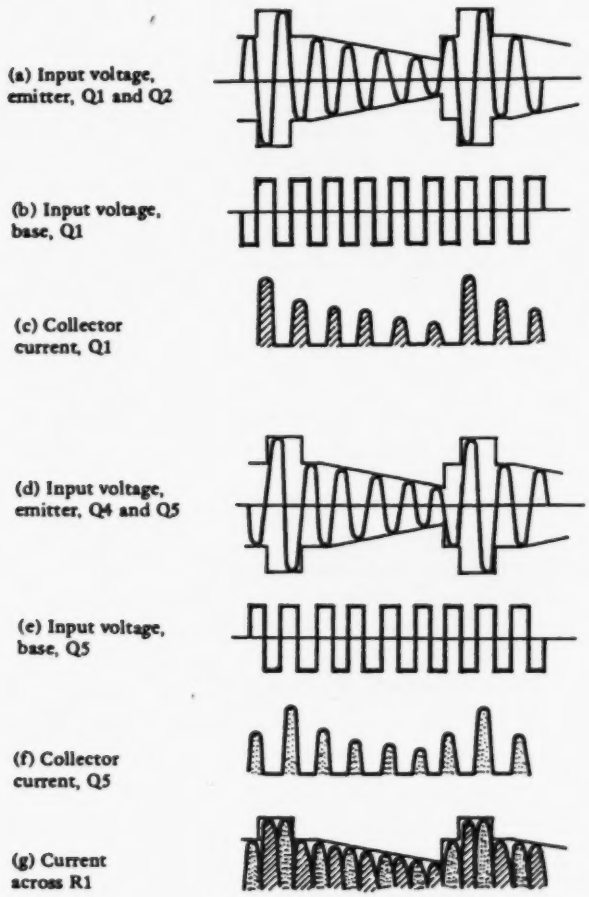

(a) Input voltage, emitter, Q1 and Q2
(b) Input voltage, base, Q1
(c) Collector current, Q1
(d) Input voltage, emitter, Q4 and Q5
(e) Input voltage, base, Q5
(f) Collector current, Q5
(g) Current across R1

Figure 2-51
Functional wave-form of a dual-balanced detector circuit

AGC circuit

AGC function

The function of the AGC is to vary the gain of IF and RF circuits in accordance with the strength of the incoming signals.

The receiver should have a higher gain when the incoming TV RF signal is weak and should have a lower gain when the incoming signal is strong.

Thus the AGC maintains a relatively constant level at the video-detector output regardless of variations in the incoming signal strength.

A constant output in the video detector is necessary for a constant contrast in the picture on the screen.

Figure 2-52 shows a block diagram of an AGC circuit.

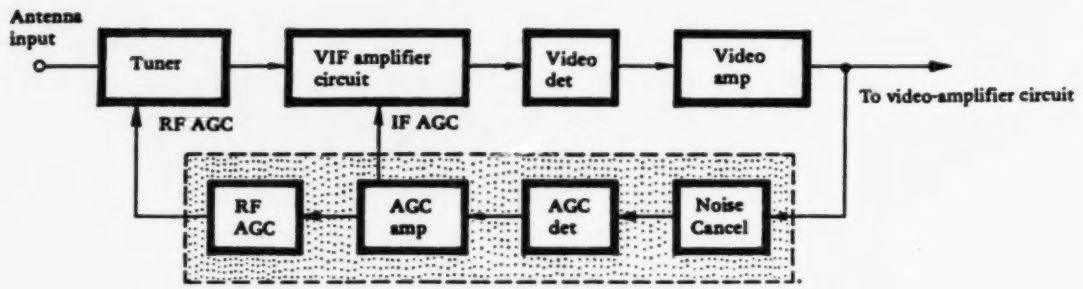


Figure 2-52
Block diagram of an AGC circuit

The AGC bias is a DC voltage whose value is determined by the strength of the incoming signals.

The level of the video-detector output indicates the strength of the RF TV signal.

The AGC voltage is supplied to the VIF amplifier and to the RF circuit in the tuner to vary their gain.

When the TV signal is strong, the AGC voltage reduces the gain of the RF amplifier circuit and maintains the gain of the VIF amplifier circuit.

However, when the incoming signal is weak, the AGC increases the gain of the VIF amplifier and maintains the gain of the RF amplifier.

AGC action

Figure 2-53 shows a graph of the current gain (h_{fe}) vs the collector current of the transistor used in the AGC circuit.

Initially, the current gain increases with the collector current. However, after a certain collector current value, the current gain decreases when the collector current is further increased. Thus the gain of the RF and VIF stages is altered by varying the collector current.

There are two opposite AGC actions used in changing the current gain of the transistors in the RF and VIF stages. These two methods are *forward* and *reverse* AGC.

In forward AGC action the gain of the transistor is decreased by increasing the collector current. This is done by increasing the forward bias at the base of the transistor towards saturation.

In reverse AGC action the gain of the transistor is decreased by lessening the collector current. This is done by reducing the forward bias at the base of the transistor towards cut-off.

Forward AGC is more often used than the reverse AGC in solid-state receivers. In receivers using FETs in the RF stage, reverse AGC is commonly used.

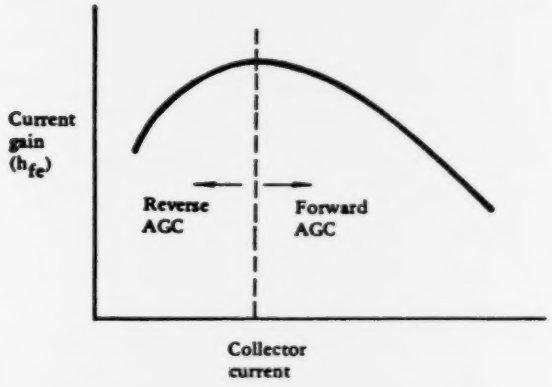


Figure 2-53
A graph of current gain (h_{fe}) vs collector current of a transistor used in an AGC circuit

How AGC voltage is taken out

There are three types of circuits which produce the AGC control voltage. They are the average value AGC circuit, the peak value AGC circuit and the keyed AGC circuit.

These circuits must have the following requirements: insusceptibility to external noises and fast response to fast-changing levels of the incoming signals such as airplane flutter.

In modern TV sets the keyed AGC and peak-value AGC are widely used.

Peak-value AGC circuit. Figure 2-54 shows a peak-value AGC circuit. Negative polarity composite video signal taken from the emitter of Q1 is fed to the base of Q2.

The output taken at the collector of Q2 is amplified positive sync signals.

C2 is charged by these sync signals after they are detected by D1.

Between the time interval of the sync signals, C2 discharges through R2.

If the time constant made by C2R2 is set longer than the horizontal scanning period, the voltage across C2 is constant and its value is proportional to the peak value of the sync signals.

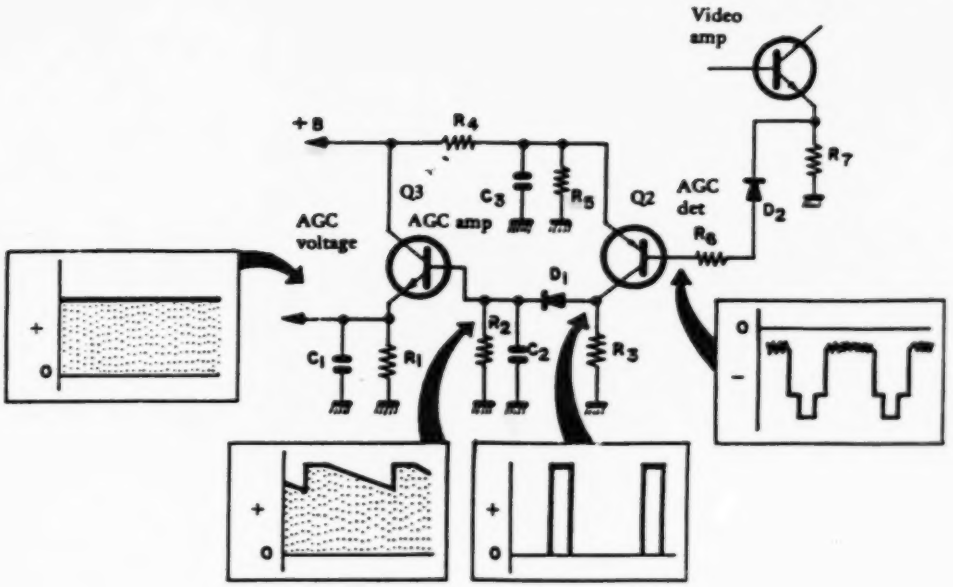


Figure 2-54
Peak-value AGC circuit

This circuit, however, is easily affected by spike or pulse noises in the video signal with amplitudes greater than or equal to the amplitude of the sync signals. These noises cause AGC action even though the strength of the incoming signal remains constant. Thus these noises affect the gain of the circuits controlled by the AGC circuit.

A noise limiter circuit is placed at the input of the AGC circuit to prevent spike noises from affecting the AGC circuit.

Keyed AGC circuit. Unlike the peak-value AGC circuit, the keyed AGC circuit is keyed on by the horizontal sync pulses. Thus the keyed AGC circuit is active only during the horizontal sync period.

The advantage of this circuit is that it is not affected by noise pulses or spike noises present in the video signal during the trace period.

Figure 2-55 shows a keyed AGC circuit.

Negative polarity video signal is taken from the emitter of Q1 (video amplifier) and applied to the base of Q2 (AGC detector).

Horizontal flyback pulses from the flyback transformer are applied to the collector of Q2 through R14, C4 and D2.

Q2 conducts only during the presence of the horizontal flyback pulses at the collector and the sync signals at the base.

The direction of the current flow is shown in the figure. This current flow charges C3 and sets the base bias of Q3 (AGC amplifier) to negative.

When the strength of the video signal at the base of Q2 increases, C3 is charged more negatively. Thus the base voltage of Q3 decreases, increasing the collector voltage.

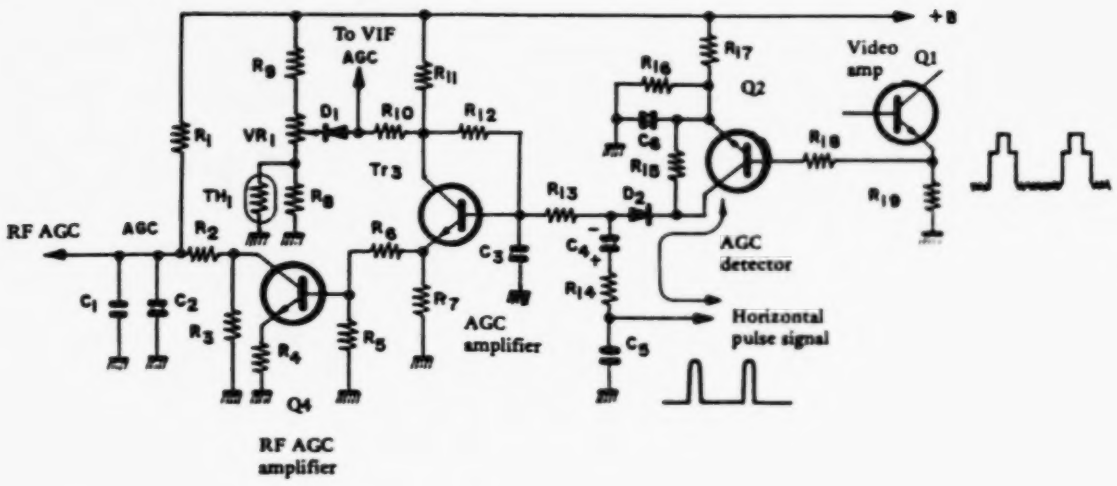


Figure 2-55
A keyed AGC circuit

The collector voltage of Q3 is the AGC voltage supplied to the base of the VIF amplifier transistor through R10. Thus the increase in the collector voltage of Q3 increases the base voltage of the VIF amplifier.

Since increasing the base voltage increases the collector current, the gain of the VIF amplifier is decreased.

Similarly, when the strength of the video signal at the base of Q2 decreases, C3 becomes less negatively charged. Thus the base voltage of Q3 increases and its collector voltage decreases.

As a result, the AGC voltage decreases the base voltage of the VIF amplifier and increases the gain.

Video-amplifier circuit

Function of the video-amplifier circuit

The function of this circuit is to amplify the video signal (mainly the luminance (Y) signal). The luminance (Y) signal is amplified to a magnitude sufficient to drive the colour CRT.

The driving voltage required by a colour CRT depends on its type. It is generally around 50 to 150 Vp-p. The video-detector output voltage is about 1 to 2 Vp-p, so it has to be amplified 50 to 100 times by the video-amplifier circuit.

Besides amplifying the Y signal, the video amplifier performs the following functions: a) distributes the composite video signals to the sync and the bandpass amplifier circuits; b) delays the luminance signal to synchronise its arrival to the colour CRT with the arrival of the colour signals; c) restores the DC component of the video signal; and d) compensates the distortion of the mid- and the high-frequency components of the video signal.

Block diagram of the video-amplifier circuit

As shown in Figure 2-56, the video-amplifier circuit consists of three to four stages.

There are two ways of driving the colour CRT. One is called the primary-colour signal drive and the other is the colour-subtraction signal drive.

The video-amplifier circuit shown in Figure 2-56 is a five-stage amplifier, with the first amplifier stage included inside an IC.

The first video-amplifier circuit distributes the video signal to the sync and bandpass amplifier circuits as well as to the succeeding second video-amplifier circuit.

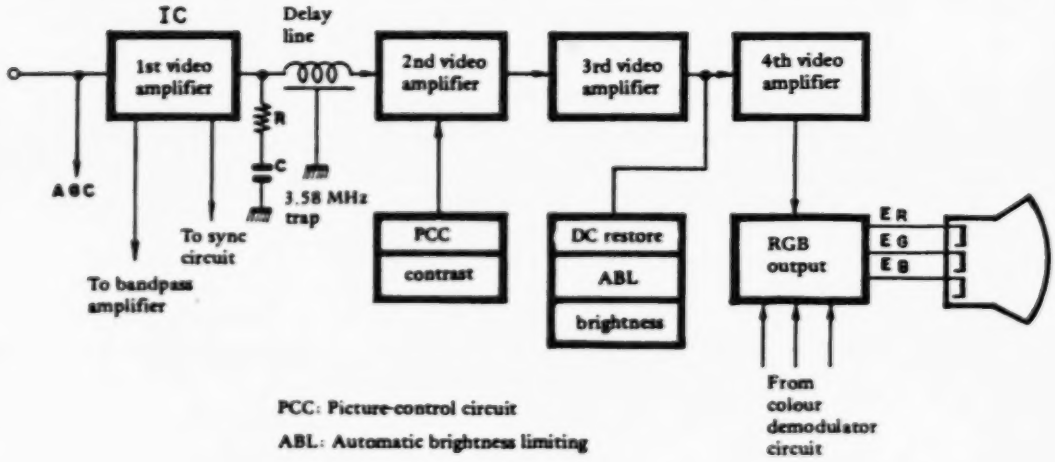


Figure 2-56
Block diagram of a video-amplifier circuit

The contrast and the sharpness circuit, which controls the softness or sharpness of the picture, is included in the second video-amplifier circuit.

The brightness, video signal DC component-restoring and ABL (automatic brightness limit) circuits are included in the third video-amplifier circuit.

The ABL circuit prevents excessive anode current flow within the CRT.

To prevent the 3.58 MHz beat distortion, a 3.58 MHz trap circuit is placed between the first and second video-amplifier circuits.

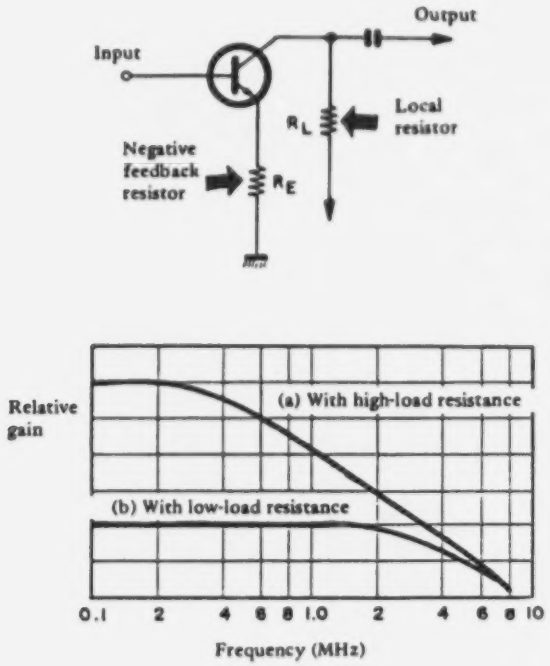


Figure 2-57
Function of a load resistor

Frequency response compensation

For the video-amplifier circuit shown in Figure 2-57, the load in the collector circuit is a low-resistance resistor. A low-resistance load enables the circuit to amplify the wide-band luminance signal.

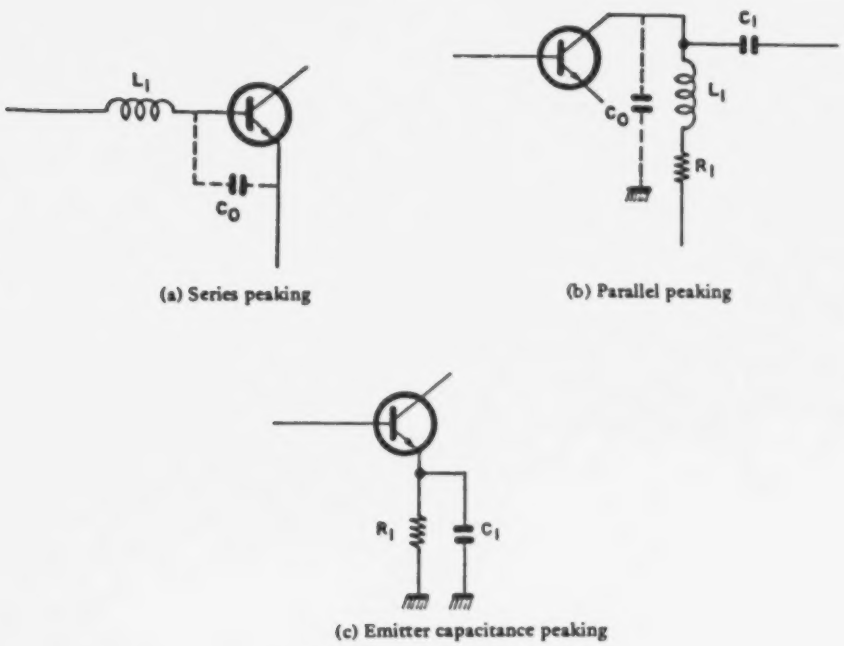
Negative feedback is also applied to the circuit to increase the bandwidth of the circuit. But because of stray capacitance due to circuit wirings and the input capacitance of the transistor, the gain in high frequencies is still less.

An inductor called a peaking coil, shown in Figures 2-58(a) and (b), is used to compensate the lesser gain of the circuit at high frequencies. The peaking coil forms a resonant circuit, the stray capacitances of the circuit boosting the strength of the high-frequency components of the video signal.

A small capacitor connected in parallel to the emitter resistor R1 as shown in Figure (c) is another way to compensate the lesser gain in the high-frequency

component of the video signal. It reduces the negative feedback at high-frequency component, increasing the gain.

The value of the peaking coil and the capacitor will change the frequency of the resonant circuit.



(a) Series peaking

(b) Parallel peaking

(c) Emitter capacitance peaking

Figure 2-58
High-frequency compensation circuits

The load resistor and the feedback resistor determine the amount of frequency compensation. In some cases, a resistor is connected in parallel to the peaking coil to decrease the Q of the coil. It buffers excessive compensation.

Figure 2-59 shows an overall response of the video-amplifier circuit.

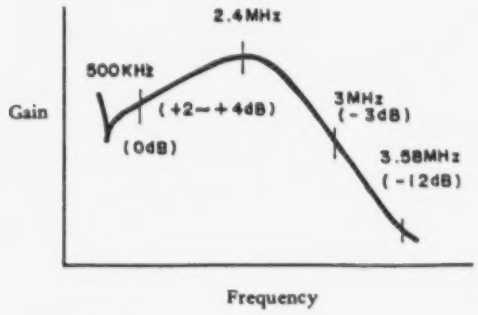


Figure 2-59
Frequency response in video-amplifier circuit

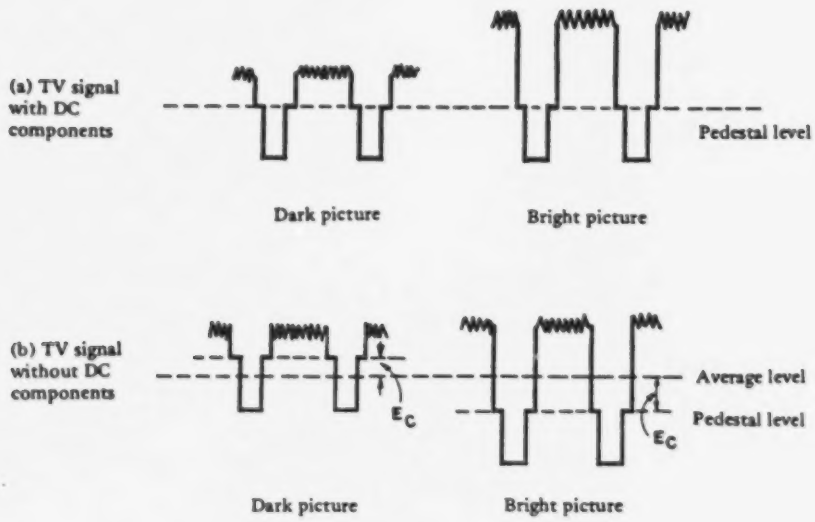


Figure 2-60
Video signal with/without DC components

Transmission of DC component

As shown in Figure 2-60(a), the pedestal levels of the video-detector output are constant in a TV signal. However, if the TV signal is amplified by an ordinary CR-coupled amplifier circuit, the DC component of the signal will be lost.

When this happens, the pedestal levels of the sync signals of the brighter part of the video signal are not equal to the pedestals of the darker part of the video signal as shown in (b).

Figure 2-61 shows an example. If a video signal with a big change in contrast is applied to the base of Q1, the collector voltage is greatly changed. The change in the collector voltage modifies the charging voltage of C3 (voltage across R5 or base voltage of Q2). The change in the base voltage of Q2 results in a change in pedestal level at output.

When a video signal without constant pedestal levels, such as the one shown in Figure 2-62, is fed to the CRT, the white signal will be reproduced as a grey colour on the screen due to the lack in DC components of the video signal.

To prevent the loss of DC components from the video signal, one uses a direct coupling circuit or a resistor coupling circuit (a resistor is connected in parallel to the coupling capacitor).

With these circuits, the DC component of the video signal is coupled to the succeeding stages. However, even with these coupling circuits, the DC component level is still insufficient. Therefore a DC restoring circuit is needed in the video-amplifier circuit.

This sets the pedestal of the sync signals of the brighter and darker parts of the video signal to the same level.

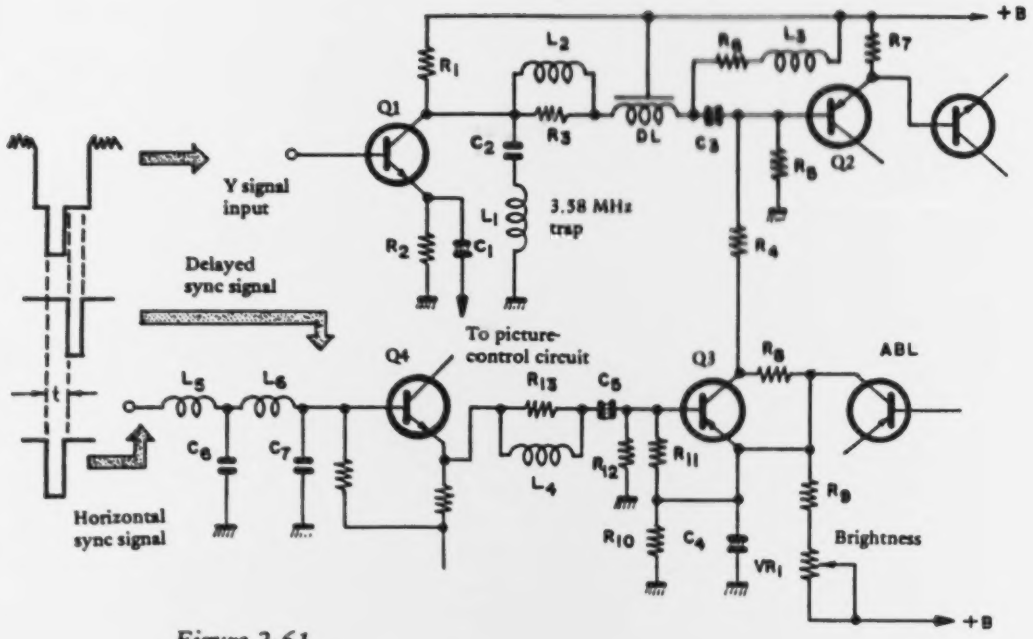


Figure 2-61
A DC restoration circuit

Figure 2-61 shows a DC restoration circuit. This circuit is called the pedestal clamp.

Delay line

Figure 2-59 shows the frequency response of the video-amplifier circuit.

Since the bandwidth of the chroma circuit is around 0.5 MHz, the difference between the bandwidth of the video-amplifier and chroma circuits results in a different processing speed for the video and chroma signals.

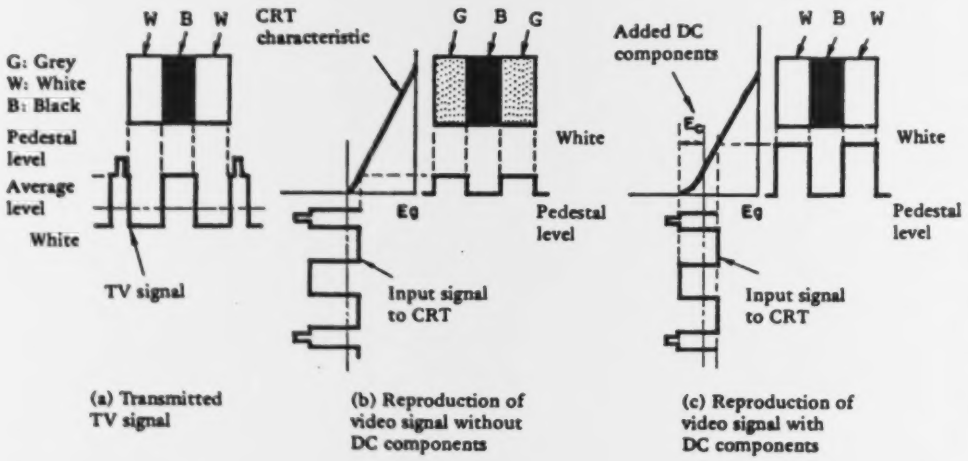


Figure 2-62
Video reproduction with/without DC components

The signal in the chroma circuit is delayed with respect to the signal in the wide-band video amplifier.

This results in different time arrivals of the colour and luminance signals at the CRT and in a double image on the screen.

Figure 2-63 shows the structure of a delay coil used for the delay line.

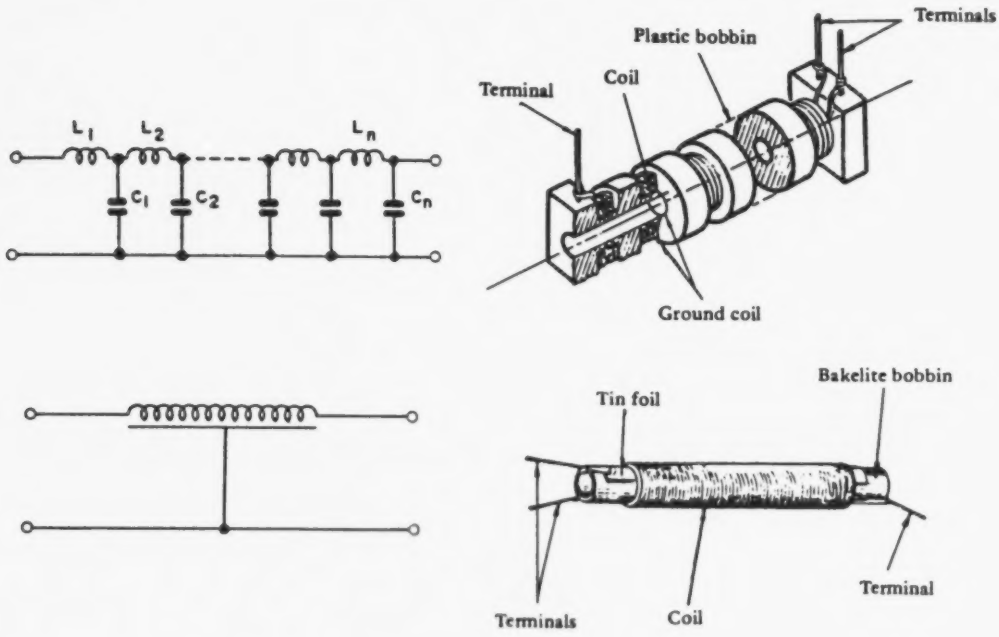


Figure 2-63
Structure of a delay coil

Sharpness-control circuit

As far as sharpness is concerned, human eyes are more sensitive to video-signal components with frequencies ranging from 1 to 2 MHz.

The sharpness of the image on the screen is varied by controlling the negative feedback in the video-amplifier circuit.

The negative feedback which controls the gain of the stage can be varied by adjusting VR1 in Figure 2-64.

The resolution of the image on the screen decreases at high-frequency video-signal components. This is due to the aperture characteristic of the CRT.

A special compensation circuit is used to improve the aperture characteristic of the colour CRT. Figure 2-65 shows an aperture-control circuit.

Contrast and brightness control

Contrast control. There are two ways to control the contrast of the image on the screen. One is to vary the amount of negative feedback in the video amplifier to control the gain of the stage, and the other is to control the strength of the video signal at the input of the video amplifier.

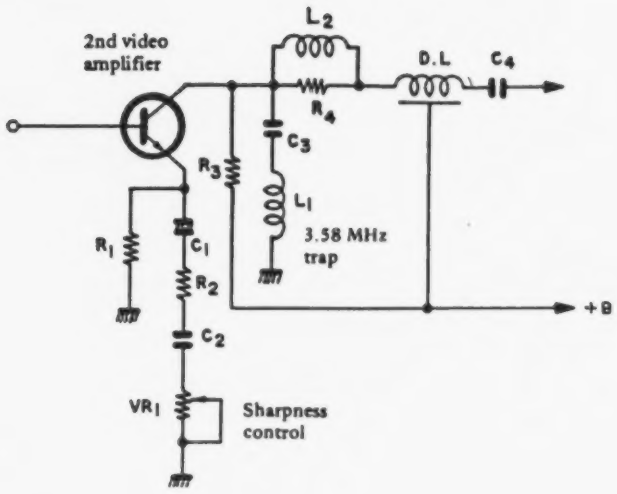


Figure 2-64
Video-sharpness circuit

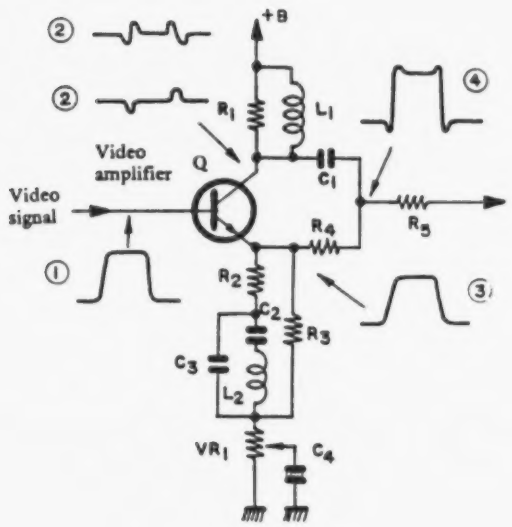


Figure 2-65
An aperture-control circuit

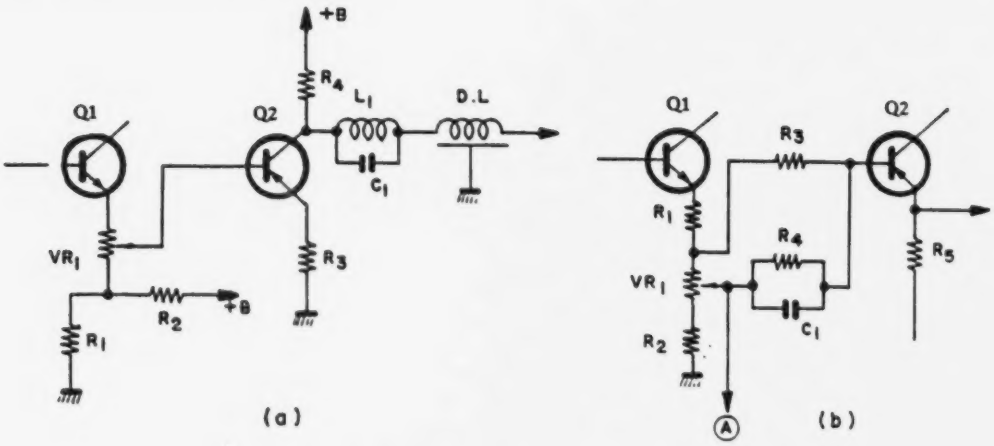


Figure 2-66
Contrast-control circuits

Figure 2-66 shows two contrast-control circuits. In both cases, the contrast is varied by adjusting VR1.

For the circuit in (a), the strength of both DC and AC components in the video signal is varied. Thus the brightness and the contrast of the image are both varied by VR1.

In Figure (b), the DC component is coupled to Q2 by R3. The value of R3 is negligible compared with the value of R4. Thus, adjusting VR1 will not cause a noticeable change in the brightness of the picture.

However, since C1 offers a low impedance path to AC signals, the AC component of the video signal coupled to Q2 can be varied by adjusting VR1. Thus the brightness of the image on the screen remains relatively constant while varying the contrast.

Brightness control. The brightness of the raster in colour CRTs can be varied by changing the base or the emitter voltage of the video-amplifier transistor.

Figure 2-67 shows two examples of brightness-control circuits.

The base voltage of the video-amplifier transistor is controlled in the circuit in (a). In this circuit two variable resistors control the brightness. VR2 is for the brightness control, VR1 for the sub-brightness control. VR1 determines the maximum brightness.

Figure (b) shows a circuit that controls both the base and emitter voltages of the video-amplifier transistor. The brightness is controlled by VR2, which is connected in the emitter circuit. VR1 is for the sub-brightness control and is connected to the base circuit.

Since the video-amplifier output is directly coupled to the CRT, the cathode voltage of the colour CRT is also varied by the brightness control. Hence the brightness of the raster on the screen is controlled.

Automatic brightness-limiting (ABL) circuit

This circuit protects the horizontal output transistor from being damaged by high beam currents at excessive brightness. Excessive brightness results in large

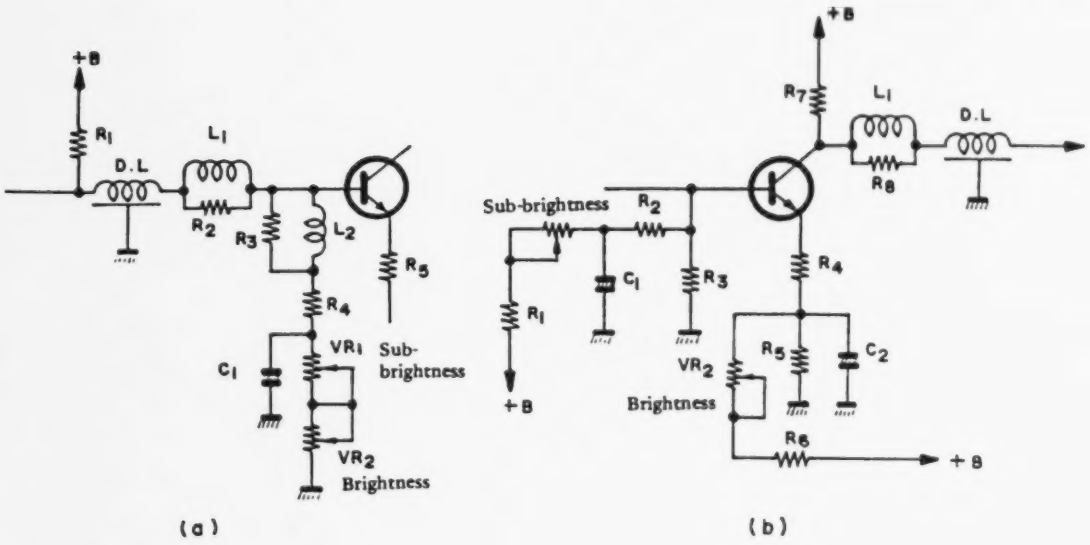


Figure 2-67
Brightness-control circuits

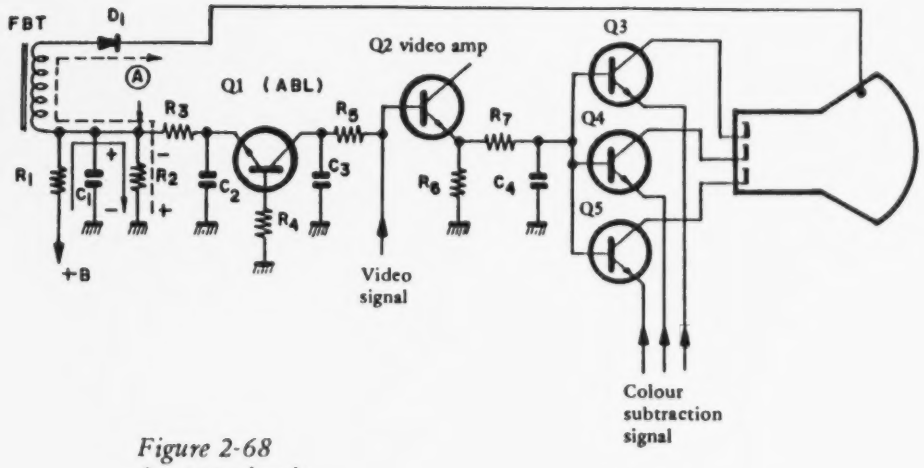


Figure 2-68
An ABL circuit

anode current in the CRT, which overloads the high-voltage circuit.

The ABL circuit detects changes in the current within the FBT (flyback transformer). When an excessive flow is detected, a negative feedback is supplied to the video-amplifier circuit to automatically reduce the brightness and thus reduce the current through the FBT.

Figure 2-68 shows an ABL circuit.

The current from the B+ supply indicated by the solid line flows through R1 and R2 and produces a positive voltage at point (A).

The anode-current flow is indicated by the dashed line. The polarities of the voltages produced by the anode and B+ supply currents across R2 are opposite.

The magnitude of the voltage produced by normal anode currents across R2 is less than the magnitude of the voltage produced by the B+ supply current. Thus, during normal conditions, point (A) is maintained at a positive potential which keeps Q1 in cut-off.

When the brightness becomes excessive, the anode current increases such that the voltage it produces across R2 sets point (A) at a negative potential. This turns on Q1.

As Q1 conducts, the base voltage of Q2 decreases. Consequently, the base voltages of Q3, Q4 and Q5 decrease. This increases the cathode voltage of the colour CRT, thus decreasing the anode current as well as the brightness.

Blanking circuit

White diagonal retrace lines will appear on the screen if the CRT is on during the horizontal and vertical retrace period.

The blanking circuit serves to turn off the CRT during the retrace time to eliminate the diagonal lines on the screen.

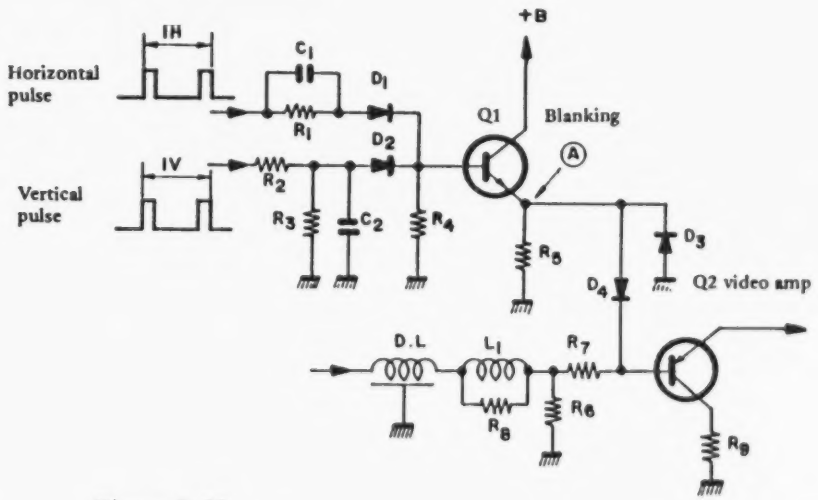


Figure 2-69
A blanking circuit

Figure 2-69 shows a blanking circuit.

Positive horizontal and vertical pulses are applied to the base of Q1 during the retrace period. These pulses keep Q1 on during the retrace period.

When Q1 conducts, the voltage at point (A) approximates the B+ voltage. This forward-biases D4.

The voltage drop across R7 and R6 produces a positive voltage at the base of Q2. This switches off Q2. D3 clips off the negative parts of the vertical and horizontal pulses.

Actual video-amplifier circuit

Figure 2-70 shows a primary-colour signal-drive video-amplifier circuit. It consists of four stages, including the amplifier circuit within the IC.

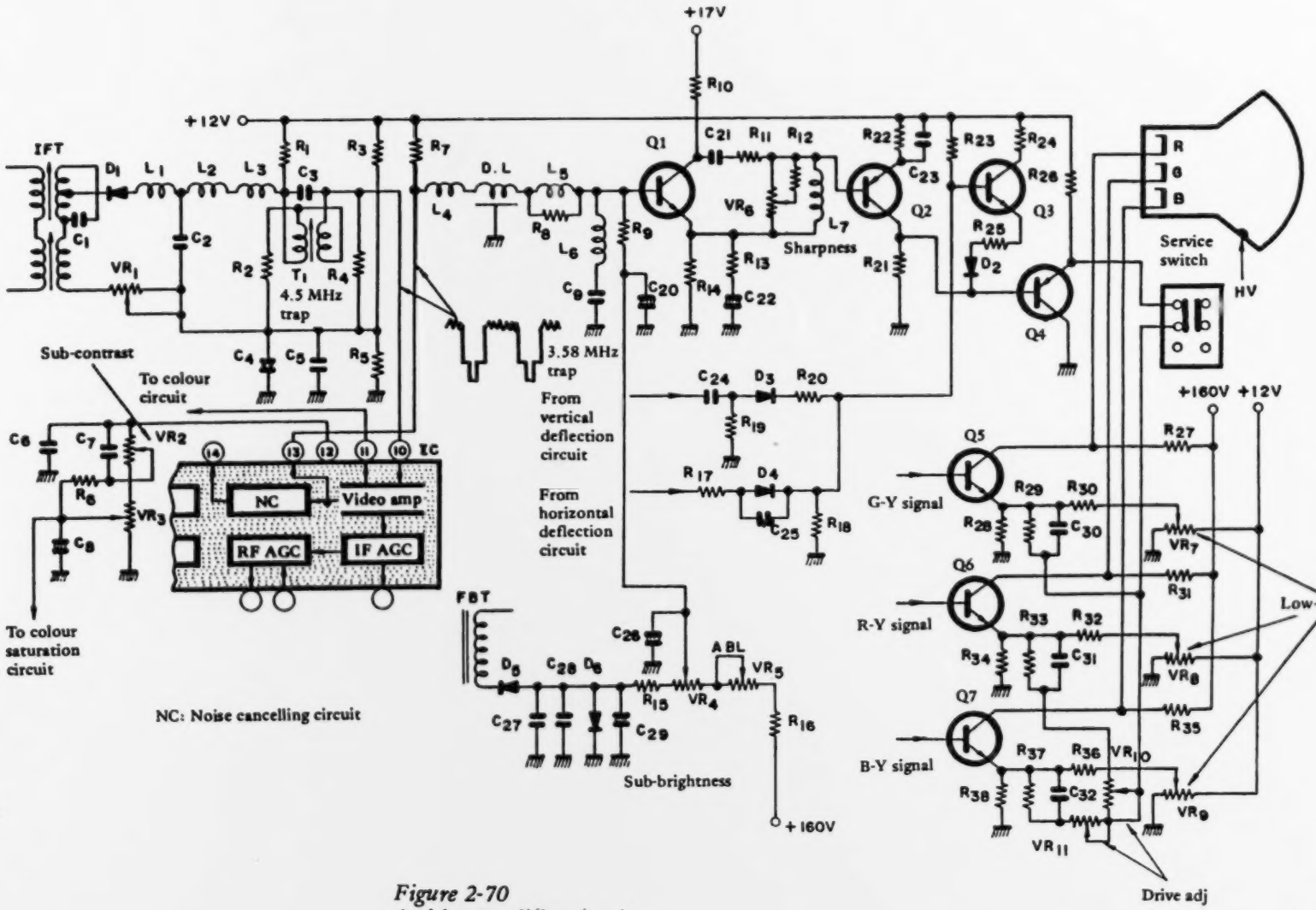
The composite video signal taken at the cathode of D1 is fed to the first video-amplifier circuit inside the IC. The low-pass filter and the 4.5 MHz sound trap circuits are located at the input circuit of the IC. The output is taken from pins 11 and 13 and supplied to the delay line (DL) preceded and succeeded by matching coils L4 and L5, respectively. The signal furthermore passes through the 3.58 MHz trap circuit to separate the 3.58 MHz chroma signal before the video signal is fed to the base of Q1.

The ABL circuit, which is the base circuit of Q1, is controlled by VR5.

The amplified video signal at the collector of Q1 is differentiated and mixed with the signal from the emitter of Q1 and then fed to the base of Q2. This is the picture-sharpness circuit discussed in the section on "Sharpness-Control Circuit." The output at the collector of Q2 is fed to the base of Q4. Q4 is controlled by Q3. Blanking pulses are supplied to Q3 and switch on Q3 during retrace periods. When Q3 conducts, the base voltage of Q4 is driven to a positive value, which turns off Q4. This circuit is the blanking circuit.

The output at the emitter of Q4 is fed to the emitter circuits of the R, G and B primary-colour signal-output transistors Q5, Q6 and Q7, respectively. The colour-subtraction signals are independently supplied to the bases of Q5, Q6 and Q7. The matrixed colour and luminance signals are taken from the collectors.

In the colour-subtraction drive system, the luminance (Y) signal alone is coupled to the cathode of the CRT from the collector of the last video-amplifier transistor.



64

65

Figure 2-70
A video-amplifier circuit

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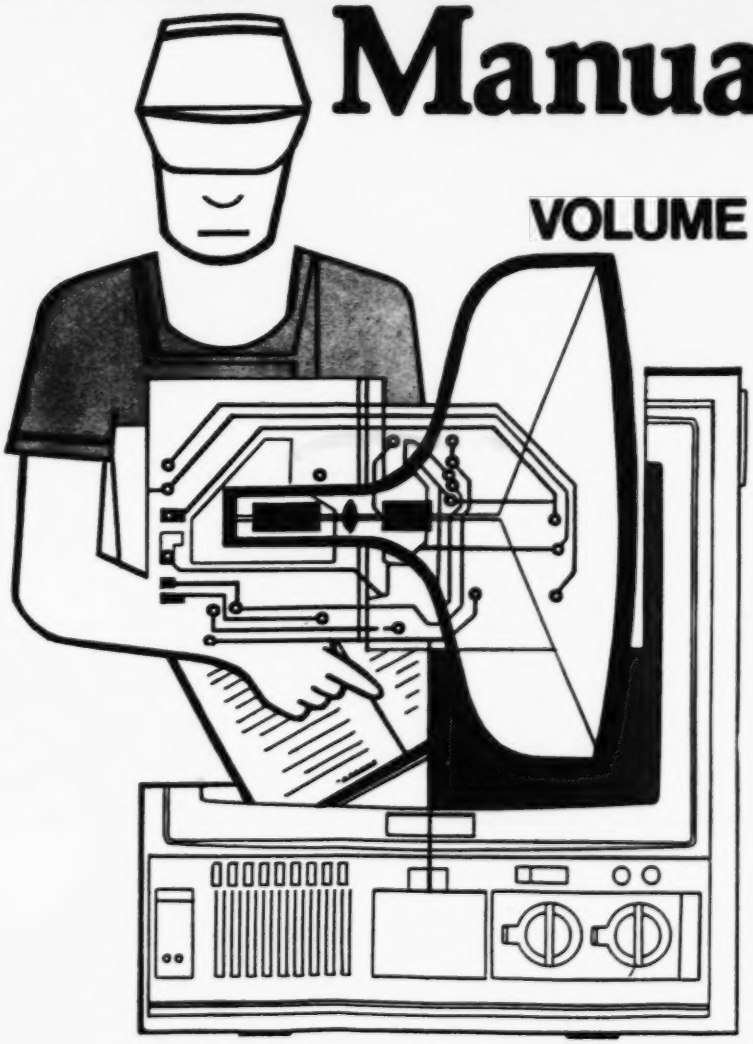

BY MASAAKI MUKAI AND RYOZO KOBAYASHI

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Teaching and training material for instructors for the training of television set technicians – Explains structure and function of the tuner, video intermediate frequency, video detector, AGC and video amplifier circuits. Circuit diagrams.

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68

TV Trouble-shooting Manual

VOLUME 6

BY MASAAKI MUKAI AND RYOZO KOBAYASHI

Part 2: Video signal processing circuit (Instructor's manual)

ASIAN AND PACIFIC SKILL DEVELOPMENT PROGRAMME
INTERNATIONAL LABOUR OFFICE
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Contents

Part 2: Video signal processing circuit

The tuner 1
Video intermediate frequency (VIF) amplifier circuit 27
Video-detector circuit 39
AGC circuit 44
Video-amplifier circuit 48

Part 2: Video signal processing circuit

This chapter deals with the functional details of the circuits from the tuner to the video-amplifier circuit inclusive.

The tuner

Structure and function

The tuner consists of three sections: the input, the RF amplifier and the converter (mixer and oscillator). (See Figure 2-1.) The tuning circuit of the RF amplifier in the tuner tunes to the RF signal of the desired TV station. The RF TV signal of the desired station is amplified by the RF amplifier, and processed into a video intermediate frequency (VIF) signal by the converter circuit.

The VIF signal is coupled to the VIF amplifier circuit for further amplification. The tuner should satisfy the following characteristics for a good image reproduction on the screen.

Matching. For a good transmission of the RF signals received by the TV antenna to the receiver, the impedance (Z_0) of the feeder cable should be equal to or match the input impedance (Z_1) of the receiver at the antenna terminals. The procedure of setting these impedances equal is called *impedance matching.* The matching impedance for VHF is 300Ω. The VSWR (voltage standing wave ratio) shows the degree of matching.

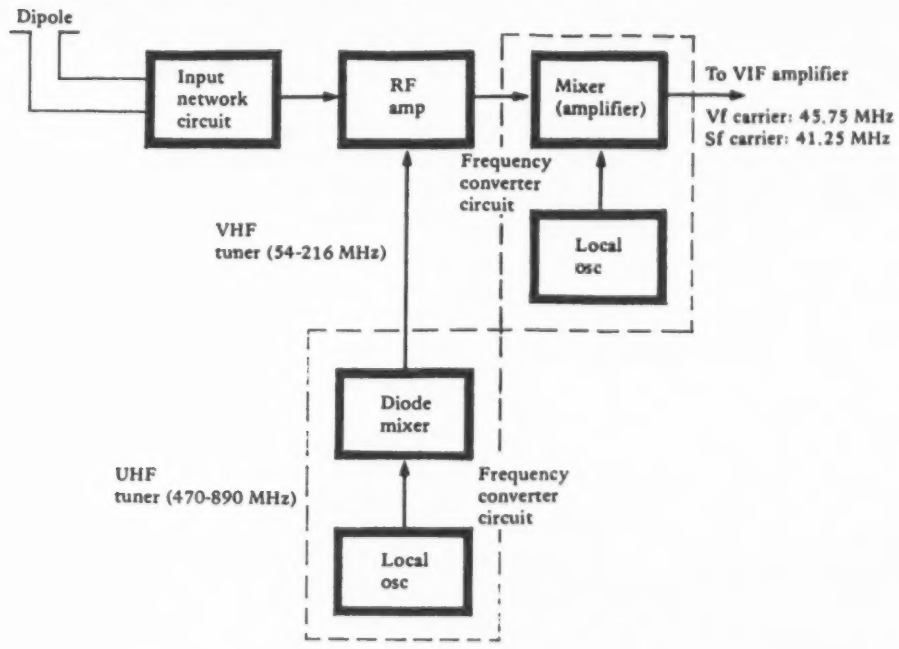


Figure 2-1
Block diagram of tuner circuit

Figure 2-2 shows the input signal (V_i) fed to the antenna terminals of a receiver. This signal is reflected by the terminals, generating a reflected signal (V_r). The interference between V_i and V_r produces an RF signal voltage that swings around V_i from a minimum value (V_{min}) to a maximum value (V_{max}). This RF signal generated on the feeder cable is a standing wave with an amplitude equal to V_r. The ratio of V_{max} to V_{min} is the VSWR. This ratio is given by the formula below:

$$VSWR = \frac{Vmax}{Vmin} = \frac{Vi + Vr}{Vi - Vr} = \frac{+ Rr}{- Rr} \qquad \ldots . 2.1)$$

where $R_v = (Z_1 - Z_0) / (Z_1 + Z_0)$

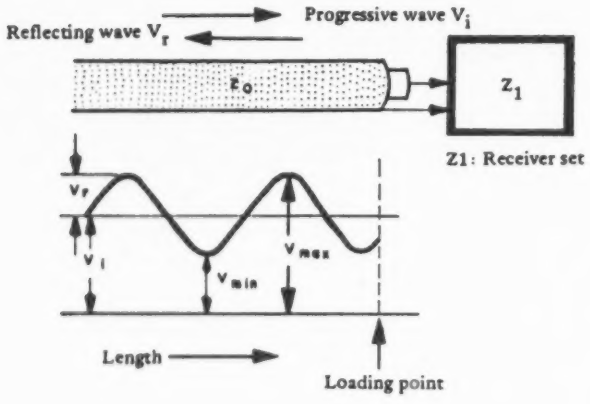


Figure 2-2
Reflection by mismatching

Ideally, the VSWR for all channels should be equal to one (VSWR = 1). This means that no standing wave is generated on the feeder cable. This happens when the matching of the impedance of the feeder lines and the input impedance of the receiver is perfect ($Z_1 = Z_0$). However, due to limitations in practical applications, perfect impedance matching cannot be obtained. Nevertheless, a VSWR less than two (VSWR < 2) is acceptable. Poor matching will result in poor image resolution and saturation of colour.

Bandpass characteristic. The frequency response curve within the 6 MHz band of each channel should be as flat as possible. As shown in Figure 2-3, the variation in the gain of the tuner within the 6 MHz band of the RF signal must not be more than 1 dB.

Noise figure (NF). Since the tuner circuit amplifies a very weak RF signal, the noise generated by the tuner circuit should be as small as possible. The noise figure (NF) gives the signal-to-noise ratio from the input to the output of the tuner. This is shown by the formula below:

$$NF = \frac{Si\ Ni}{So\ No} \qquad \begin{matrix} Si\ Ni: \text{input SN ratio} \\ So\ No: \text{output SN ratio} \end{matrix} \qquad \ldots . 2.2$$

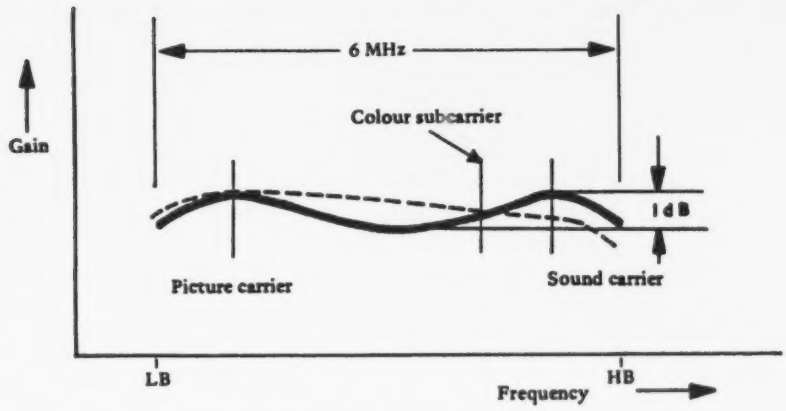


Figure 2-3
Tuner bandpass response

In equation 2.2 the ideal value for NF is one (NF = 1), corresponding to a zero loss (0 dB) in the signal-to-noise ratio. For present VHF tuners the usual value of NF is between 4 dB and 5 dB. The value depends on the characteristic of the transistor, the coupling circuit used and the selectivity of the tuning circuit.

Cross-modulation and mutual modulation. When the TV receiver is located in an area where the field strength of a TV station is very strong, the signal of this station is radiated or coupled directly to the VIF circuit. This will interfere with the signal of the tuned-in station, resulting in an image with a beat distortion. This distortion is commonly called the "windshield-wiper" distortion.

This interference results from the non-linear response of the tuner circuit which depends on the AGC (automatic gain control) characteristic. Present TV receivers, however, are designed so that the windshield-wiper effect does not occur as long as the interfering TV signal strength is less than 100 dB.

Stability of the local oscillator. A drift in the local oscillator frequency will result in poor image reproduction, and RF signals of adjacent channels may interfere with the signal of the tuned-in station. The oscillator should have a stable design to minimise drift in the oscillation frequency. The frequency should be within +100/-200 kHz of the required frequency. An AFC (automatic frequency control) circuit is connected to the local oscillator to stabilise its oscillation. A drift in the oscillator frequency due to ageing cannot be avoided, but can be minimised by including the AFC circuit. In Figure 2-4 the drift in the oscillator frequency is plotted with respect to time. The drift is not too large, because the AFC circuit is included.

In UHF reception a radiated local oscillator signal will cause interference in nearby receivers. This signal will beat with the signal of a TV station nine or ten channels away. Thus precautions have to be taken to prevent the antenna from radiating the local oscillator signal.

Local oscillator signal radiation does not result in interference in VHF reception, since the receiver's IF signal is selected such that the local oscillator

frequency for any VHF channel is not included in the frequency band of any VHF channel.

Input circuit

The function of the input circuit is to match the input impedance of the receiver at the antenna terminals and the impedance of the feeder line. It also converts a balanced (300-ohm feeder cable) coupling to an unbalanced coupling (75 ohms, the input impedance of an RF circuit).

Two types of coupling circuits are commonly used in TV receivers. They are 1) the M-coupling circuit, which is used in UHF tuners, and 2) the balanced-coupling circuit, which is used in VHF tuners.

The balanced-coupling circuit uses a transformer called "balun." Feed-through bypass capacitors are generally used for bypassing the B+ and AGC lines into the RF tuner. L2 is a coaxial cable with one-half or one-fourth length acting as parallel coils in resonance with capacitor C1.

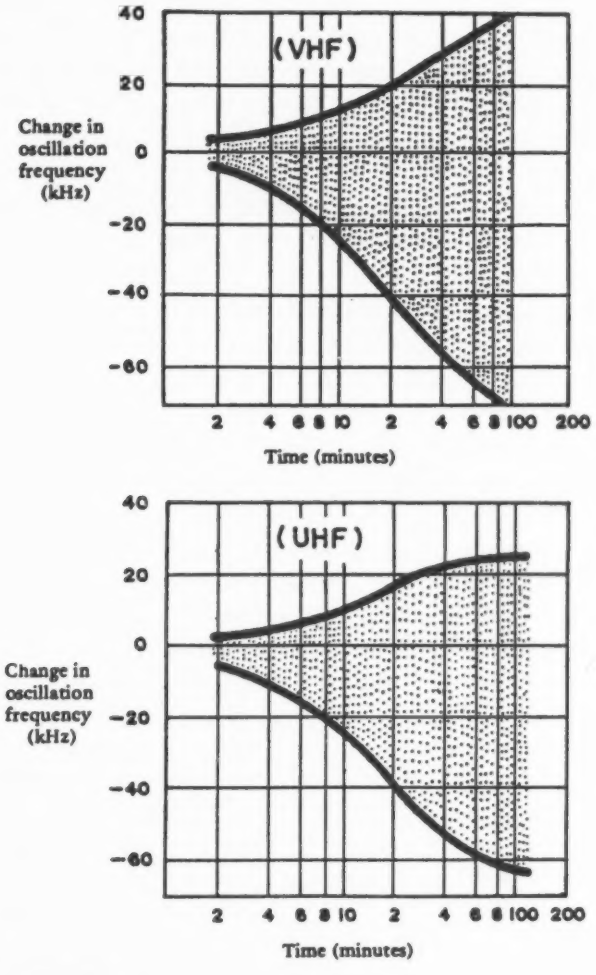


Figure 2-4
Drift in local oscillator frequency

M-coupling. M-coupling is similar to an ordinary transformer coupling in which the signals are electromagnetically coupled (inductive coupling). The secondary winding of the transformer corresponds to the input tuning circuit of the RF amplifier stage. Figure 2-5 shows an M-coupling circuit in a UHF tuner.

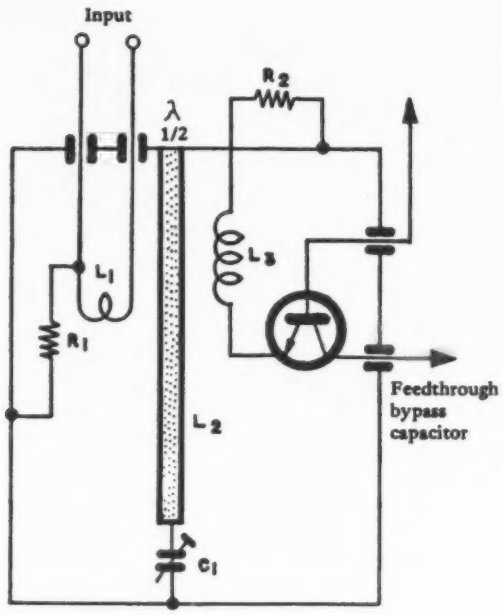


Figure 2-5
M-coupling input circuit (UHF)

Balanced, or balun transformer, coupling. There are two kinds of feeder cables that can be used to transmit the TV signals from the antenna to the receiver. One is the ordinary balanced 300-ohm ribbon cable, the other is the unbalanced 75-ohm coaxial cable. To match the input impedance of the TV receiver to the impedance of the two kinds of feeder cables, use a matching transformer with a very low conversion loss. This matching transformer is called "balun." An example of a balun unit is shown in Figure 2-6. (Balun stands for "balanced unit.")

RF amplifier section

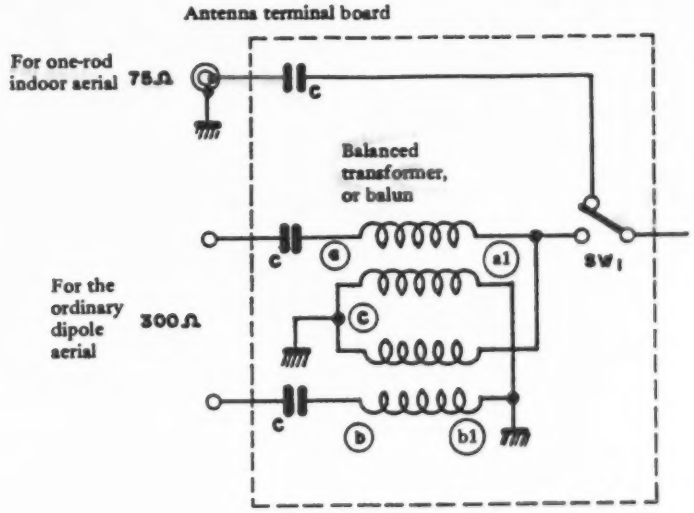
The gain of the RF amplifier should be constant within its 6 MHz bandwidth. The circuit is designed to have a high gain to compensate for the noise generated by the mixer circuit. However, the RF amplifier should have a sharp response and a high attenuation outside its bandwidth.

The RF amplifier acts as a buffer to prevent the local oscillator-generated frequency from being transmitted out of the antenna. It may interfere with nearby TV receivers.

The RF amplifier consists of an input filter, an antenna tuning circuit and an RF amplifier transistor.

Input filter. The input filter is a high-pass filter (HPF) that blocks interfering signals with frequencies close to the VIF frequency of the receiver. (IF trap is 40-47 MHz.) Input filters trap FM frequencies 88-108 MHz to prevent the FM frequencies from interfering with the RF signal. This filter also protects the RF amplifier circuit from lightning and static charges from the external antenna.

Figure 2-8 shows an input-filter circuit. The HPF circuit is formed by C1, L3, C3, L4 and C5. The parallel circuits formed by L1 C2 and L2 C4 are parallel resonant circuits that trap VIF signals. C1, C3 and C5 block excessive voltage.



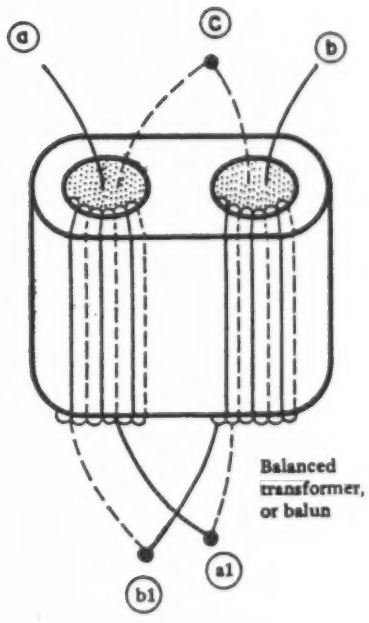


Figure 2-6
Balanced, or balun, coupling (VHF)

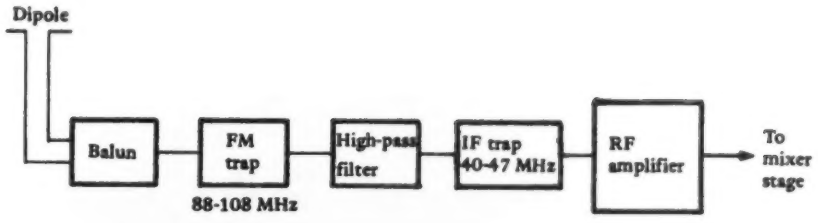


Figure 2-7
Block diagram of input circuit for RF amplifier stage

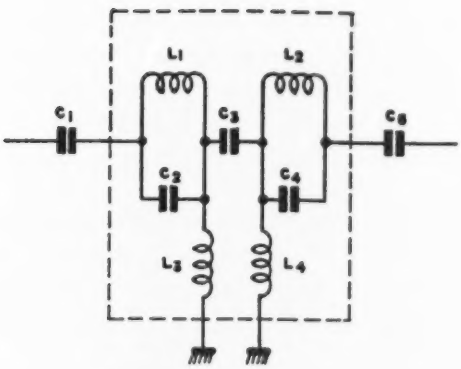


Figure 2-8
Input-filter circuit

Antenna tuning circuit. 1) VHF. Figure 2-9 shows an antenna tuning circuit for the VHF tuner. The tuning circuit is formed by coils L_{CH} and L1 and by capacitors C4 and C5. L_{CH} is channel-dependent and is replaced by other coils when the receiver is tuned to other channels. C4 is shorted when the receiver is tuned to the low VHF bands.

2) UHF. Because of high frequencies in the UHF bands, it is impractical to use a tuning circuit similar to the tuning circuit of the VHF tuner. Instead a resonant coaxial cable tuning circuit with the length of the coaxial cable either one half or one fourth of the wavelength of the resonant frequency is used.

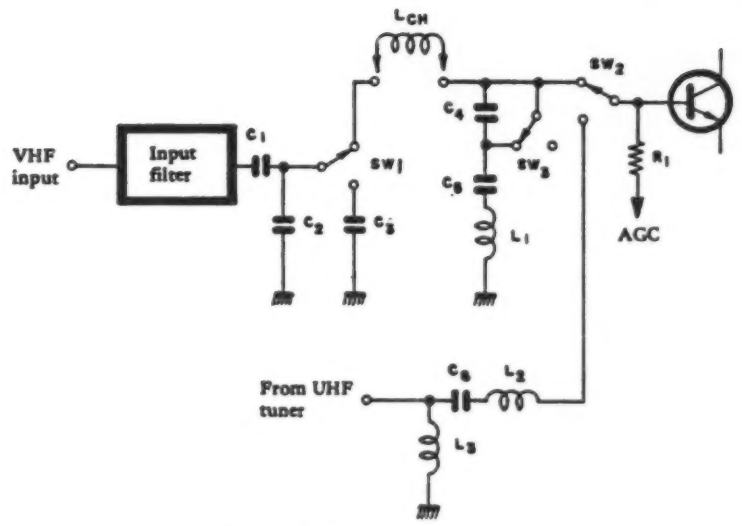


Figure 2-9
Antenna tuning circuit

When a one-fourth wavelength coaxial cable is shorted at one end, the impedance at the open end seen by resonant signals is infinite. This is similar to a parallel resonant circuit. The resonant frequency of the coaxial cable can be varied by changing its length. It is more practical, however, to vary the resonant frequency by connecting a variable capacitor at the open end of the cable, as shown in Figure 2-10(a).

A similar parallel resonant circuit can also be made, using a one-half wavelength resonant coaxial cable with both ends open, as shown in Figure 2-10(b). Similarly the resonant frequency of this resonant cable circuit can be varied by connecting a variable capacitor at one open end.

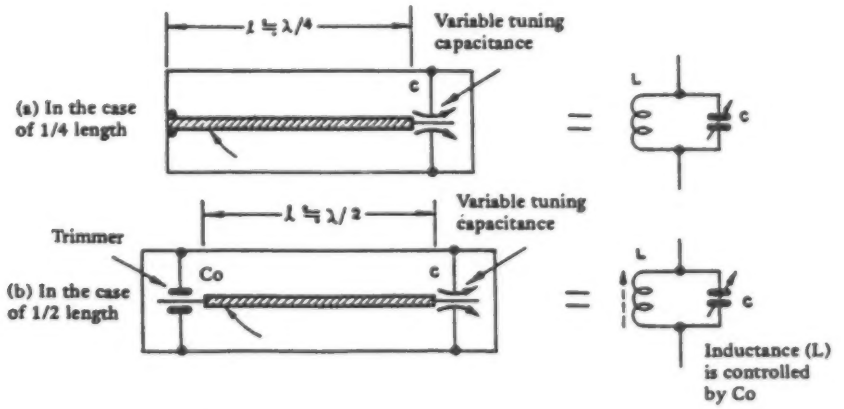


Figure 2-10
Coaxial resonance circuit

For the same resonant frequency, the lengths of the two kinds of resonant coaxial cable circuits are unequal. However, by selecting the size of the inner conductor of the coaxial cable and the value of the variable capacitors, the two resonant cable circuits can have the same length and frequency. The one-half wavelength resonant coaxial cable circuit is used in UHF tuners. This circuit is usually formed by a hollow metal container with the centre or inner conductor inside.

RF amplifier stage. A common-emitter amplifier or a FET (field-effect transistor) amplifier is usually used in RF amplifier circuits. In common-emitter amplifiers, part of the output signal serves as a positive feedback to the input because of the internal capacitance of the transistor. This feedback causes the RF amplifier to oscillate and have an unstable operation. To prevent this, a negative feedback signal is supplied to the input by Cn to counteract the effect of the positive feedback. (See Figure 2-11.) This function is called "neutralisation." This stabilises the amplifier and prevents oscillation.

A FET has high-input impedance and good dynamic linearity. This gives less cross-modulation. Usually a dual-gate MOSFET (metal-oxide semiconductor) is used. In the MOSFET amplifier circuit the RF signal from the antenna and the AGC voltage are independently supplied to the two gates. The output of the MOSFET amplifier is taken at the drain.

A common-emitter RF amplifier stage has a gain of around 20 dB, a FET RF amplifier around 15 dB.

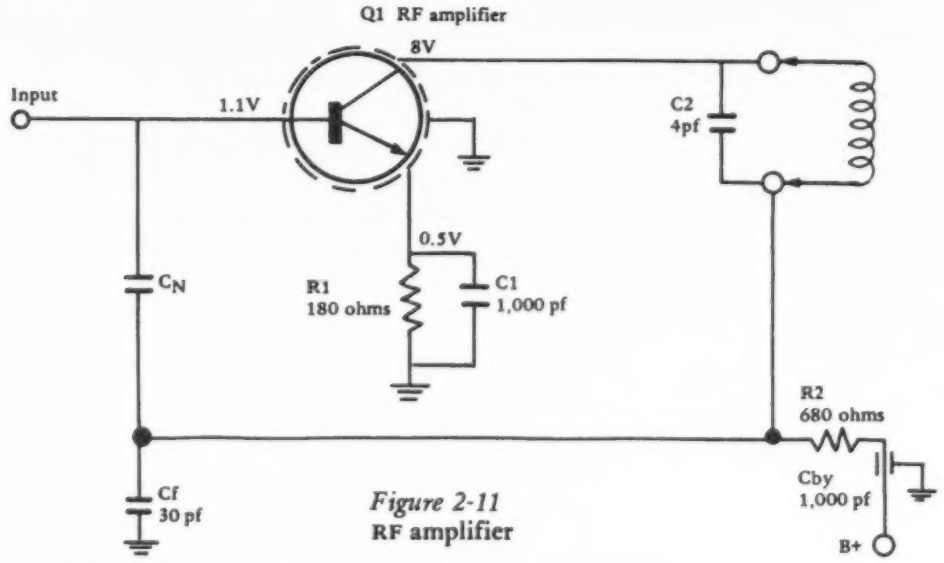


Figure 2-11
RF amplifier

Frequency converter section

The converter section of the tuner circuit converts the RF signal of the tuned-in TV station into a more stable VIF signal. The converter circuit consists of a mixer and the local oscillator stage.

Mixer circuit. The mixer circuit beats the RF signal and the local oscillator signal to produce a stable VIF signal for the VIF amplifier circuits. The frequency of the VIF signal is equal to the difference between the local oscillator frequency and the RF frequency.

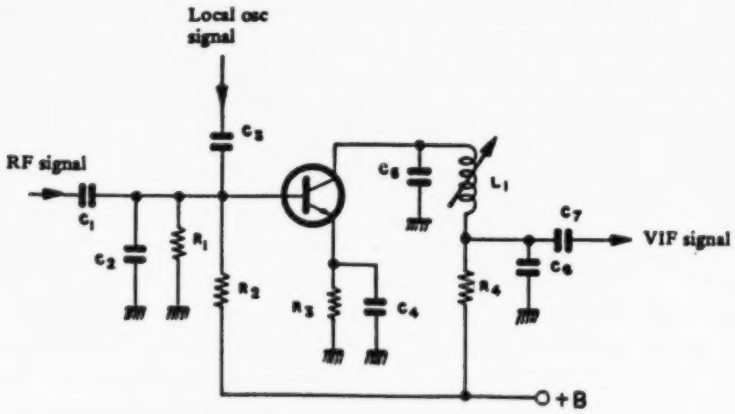


Figure 2-12(a)
VHF mixer circuit

Figure 2-12(a) shows a mixer circuit. The RF signal and the local oscillator signal are coupled by C1 and C3, respectively, to the base of transistor Q. The local oscillator signal is heterodyned with the RF signal to produce a VIF signal. The VIF output signal is taken out from the collector circuit.

The efficiency of the mixer circuit depends on its conversion gain. This gain is given by the formula below:

conversion gain = VIF output voltage / RF input voltage

This gain is usually one half to one third of the RF amplifier gain.

A diode is used as a mixer in UHF tuners. The conversion gain of a diode mixer is lower than the gain of a transistor mixer. Thus the VHF tuner is designed to operate as a VIF amplifier for the UHF VIF signals during UHF reception to boost the strength of the UHF VIF signals.

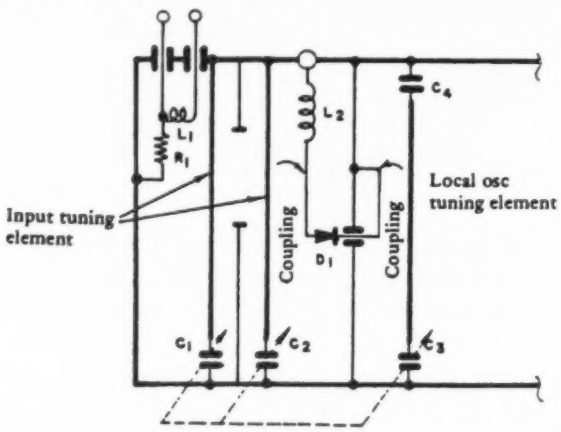


Figure 2-12(b)
Mixer circuit by diode

A special diode (alloy or point contact type) is used for the mixer in the UHF tuner to get a sufficient S/N (signal to noise) ratio. Figure 2-12(b) shows a UHF mixer circuit. The input RF signal from the UHF tuning circuit is M-coupled to the anode of D1, and the local oscillator signal is M-coupled to the cathode. The VIF output signal is taken out from the anode. L2 prevents the local oscillator signal from going to the VIF amplifier circuits.

Local oscillator circuit. The Colpitts oscillator circuit is commonly used in the local oscillator circuit because of its simplicity and stability. An example of a Colpitts oscillator circuit is shown in Figure 2-13. The oscillation frequency of the circuit can be obtained from the formula below:

$$f = \frac{1}{2\pi\sqrt{L\,\frac{C_1 + C_2}{C_1\,C_2}}}$$

Another basic oscillator circuit commonly used in the local oscillator is shown in Figure 2-14. This circuit, a modified Colpitts oscillator, is called a Krapp oscillator. It has a higher stability than the Colpitts oscillator.

A drift in the local oscillator frequency results in windshield-wiper distortion and poor image reproduction. To stabilise the oscillation of the local oscillator, special attention must be paid to the designing of the circuit and to the selection of the components. Components that compensate each other's change in characteristic due to heat and drift in the power-supply voltage are used.

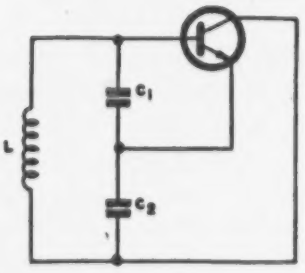


Figure 2-13
Basic Colpitts oscillator circuit

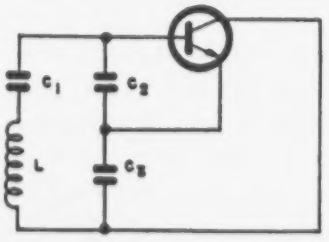


Figure 2-14
Modified Colpitts oscillator circuit (Krapp oscillator circuit)

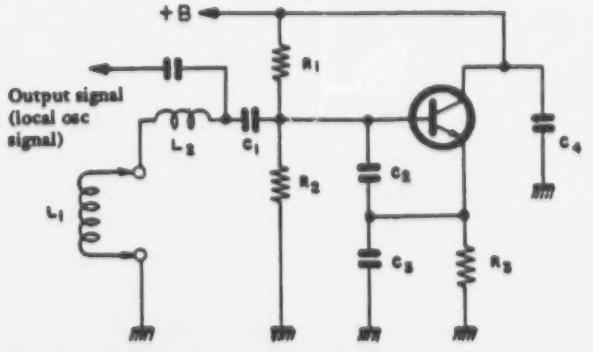


Figure 2-15(a)
A VHF local oscillator circuit

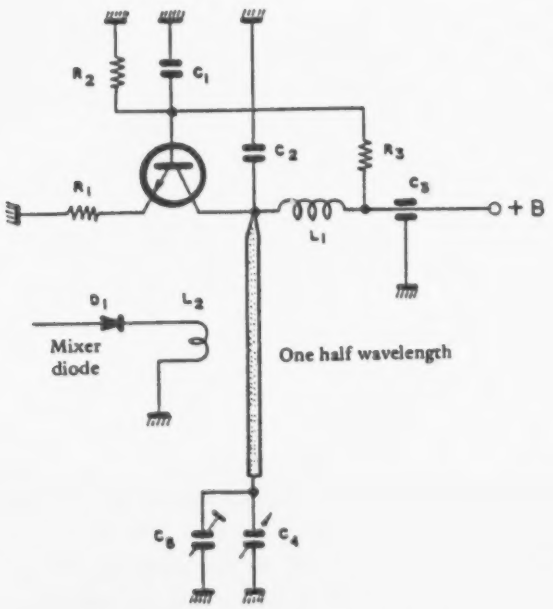


Figure 2-15(b)
A UHF local oscillator circuit

An actual VHF local oscillator circuit is shown in Figure 2-15(a). L1 is replaced whenever the channel selector is switched to another channel to enable the oscillator to vary at a unique frequency for each channel.

For a local oscillator in the UHF tuner, a one-half wavelength coaxial resonant circuit is commonly used. A one-half wavelength coaxial resonant circuit oscillates with more stability than a one-fourth wavelength coaxial resonant circuit.

Figure 2-15(b) shows a UHF local oscillator circuit. The circuit uses a modified Colpitts oscillator. Variable capacitors are connected to one end of the centre conductor of the resonant tuning circuit. The other end is connected to the collector of the oscillator transistor and to a coupling capacitor. The output signal of the local oscillator is taken out from L2 and supplied to the mixer diode D1.

Channel selection

The TV broadcast band is divided into: the VHF low-band channels 2-6 (54-88 MHz), the VHF high-band channels 7-13 (174-216 MHz), and the UHF channels 14-18 (470-890 MHz). In the Japanese TV broadcasting band the VHF band is assigned to 90-108 MHz and 170-222 MHz; the UHF band,470-770 MHz.

VHF tuner. Channel selection in conventional TV receivers is done by switching the coils in the tuner through a channel selector switch. There are three types of VHF tuners: turret, rotary and disk turret.

A turret tuner is shown in Figure 2-16(a). Each individual channel has an independent set of coils mounted on one strip. Thus, individual channel adjustment for maximum tuning and coupling is possible.

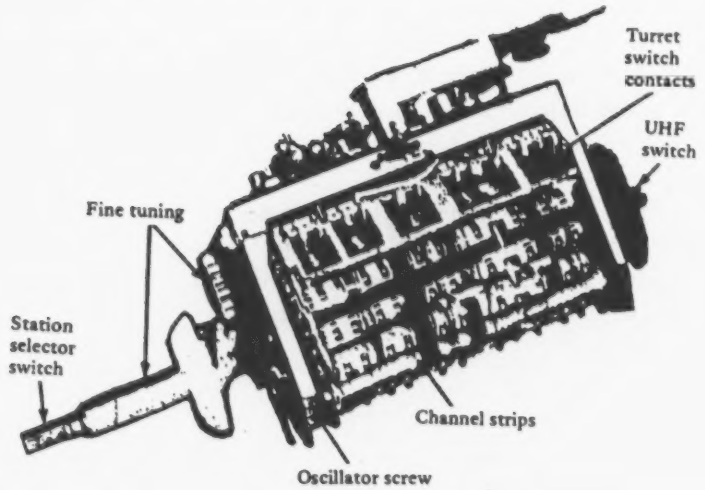


Figure 2-16(a)
Turret tuner with coil strips for each channel shield cover off

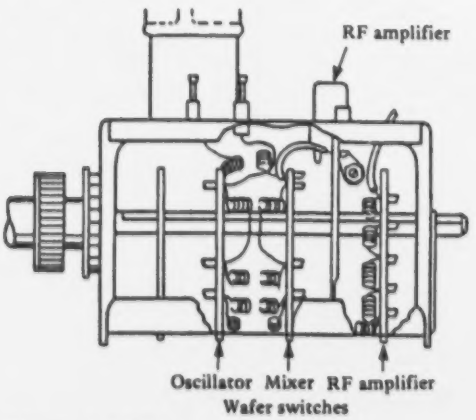


Figure 2-16(b)
Rotary-switch tuner with wafer switches for each stage

A rotary tuner is shown in Figure 2-16(b). It has rotary wafers for the tuned stages of the tuner. In every wafer the coils of the different channels are connected in series; hence individual channel adjustment is not possible.

A disk turret tuner is shown in Figure 2-16(b). This tuner arrangement is similar to the rotary tuner. The oscillator coils, mixer coils and RF amplifier coils are all mounted on their respective wafers. Unlike in the rotary tuner, however, the coils on each wafer are independent of each other. Thus individual channel adjustment is possible.

UHF tuner. Since there are so many channels in the UHF band, it is not practical to use a channel selector similar to the VHF channel selector due to the complication that will result in its design and structure. Thus a linear tuning system, similar to the tuning system in ordinary radio receivers, is used. The receiver is tuned to different UHF stations by adjusting a variable capacitor. To facilitate convenience in tuning, a mechanical detent is provided in the tuner for each channel.

Figure 2-17 shows a UHF tuner. It has a pre-set mechanism that can tune the receiver to the desired UHF channel. By simply setting the selector to the desired UHF channel, just like in VHF channel selectors, the pre-set mechanism automatically tunes the receiver to the desired channel.

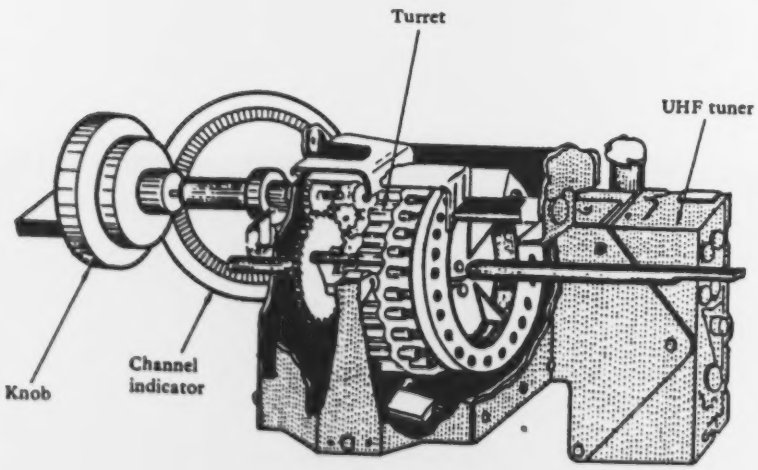


Figure 2-17
A UHF tuner

UHF and VHF tuner coupling. Modern TV sets usually have VHF and UHF tuners. As described before, the VHF tuner is used as a part of a VIF amplifier circuit when the set is tuned in to a UHF station. When the VHF selector is set to the UHF position, signals from the VHF antenna are automatically grounded, the local oscillator of the VHF tuner is disabled and proper coils are set in the VHF tuner to tune the VHF RF amplifier to the VIF frequencies. The VIF signal from the UHF tuner output is coupled to the input circuit of the VHF RF amplifier.

AFT circuit

The local oscillator is designed to vary at a unique frequency for every channel to produce the correct VIF signal (45.75 MHz picture carrier) for the VIF circuits. However, a drift in the oscillator frequency is unavoidable, because of the heat in the TV set and ageing of the oscillator circuit. To avoid excessive drift, a fine-tuning circuit and an AFT (automatic fine-tuning) circuit are connected to the oscillator for stabilisation.

The local oscillator can be fine-tuned by varying the value of an inductor or a capacitor in the circuit. In practical applications, the value of an inductor is commonly varied. A brass conductor is inserted inside the coil and the inductance is varied by adjusting the position of the conductor. However, periodic fine-tuning adjustments, each time the set is tuned to another station, are tiresome. The AFT or the ALFC (automatic local-oscillator frequency control) relieves us from the burden of constantly adjusting the fine-tuning circuit.

Figure 2-18 shows a functional block diagram of an AFT circuit. A drift in the local oscillator is detected by the circuit enclosed by the dashed lines. When a drift is detected in the local oscillator frequency, the AFT circuit sends a DC-control voltage proportional to the drift to a variable capacitor (varicap) diode in the oscillator. The control voltage varies the capacitance of the varicap to restore the local oscillator to its original frequency.

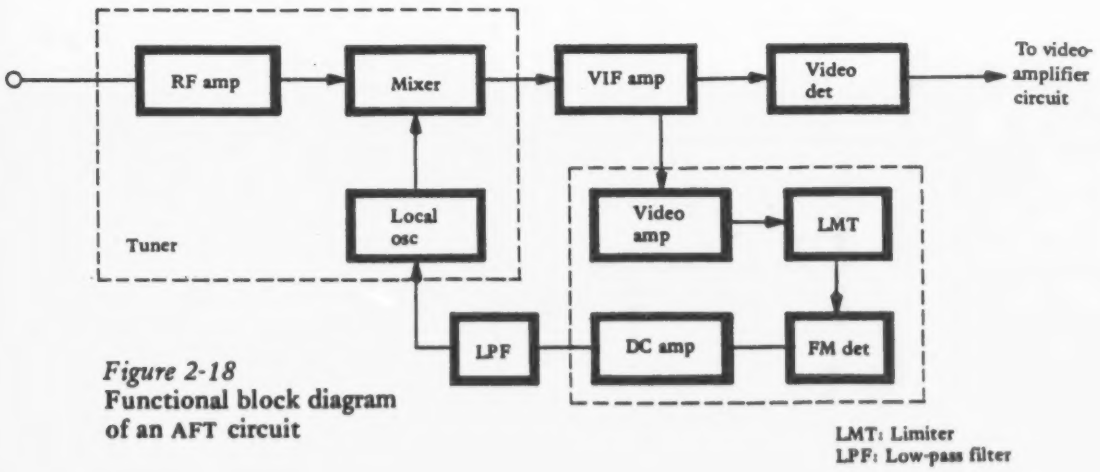


Figure 2-18
Functional block diagram of an AFT circuit

The general details in the function of the AFT circuit shown in Figure 2-19 are enumerated below:

1 The VIF signal (45.75 MHz) is tapped from the VIF amplifier circuit and then amplified.

2 Amplitude variations in the VIF signal are clipped by a limiter circuit to produce a continuous-wave (CW) VIF carrier signal.

3 The VIF carrier signal is detected by an FM detector, and drifts in the IF carrier signal from the correct IF frequency are reflected as changes in the output level of the FM detector.

4 The FM detector output is amplified and supplied as a control voltage to the varicap in the local oscillator circuit through a low-pass circuit.

The static capacitance of the varicap is inversely proportional to the reverse-bias voltage across its terminals. The variable static capacitance of the varicap is controlled to compensate for the frequency drifts in the local oscillator signal.

Let us consider a decrease in the local oscillator frequency. We know that the frequency of the VIF carrier signal is the difference between the frequency of the local oscillator and the RF carrier signal, where the oscillator frequency is always higher than the RF carrier frequency. Since the RF carrier frequency of a particular station is constant, a decrease in the oscillator frequency lessens the frequency of the VIF signal.

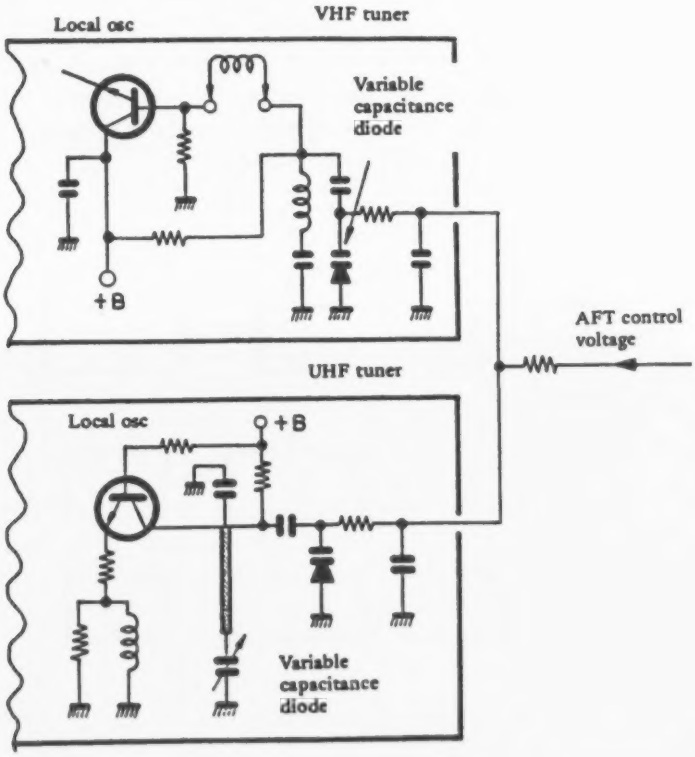


Figure 2-19
Supply of AFT voltage to the tuner circuit

To detect a frequency drift, one feeds the VIF signal to a limiter circuit to get a VIF carrier signal. Then the VIF carrier is detected by an FM detector circuit. The output of the FM detector depends on the frequency of the input signal. The FM detector is designed to produce no output when the frequency of the input signal is equal to the correct IF frequency. When the frequency of the VIF carrier signal decreases, the DC output of the FM detector increases.

Refer to Figure 2-20 for the frequency response of the FM detector. The output of the FM detector is amplified and then supplied to the varicap in the oscillator as a control voltage. This voltage controls the capacitance of the varicap to increase local oscillator frequency. Thus the decrease in the oscillator frequency is compensated.

Figure 2-21 shows an AFT circuit commonly used to control the local oscillator circuit.

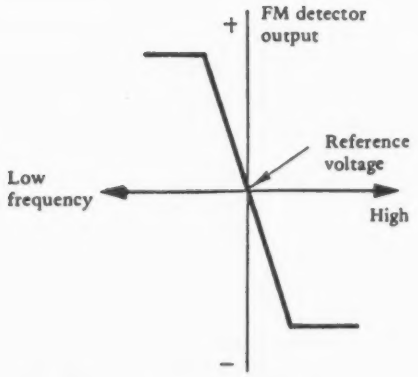


Figure 2-20
Frequency response of the FM detector

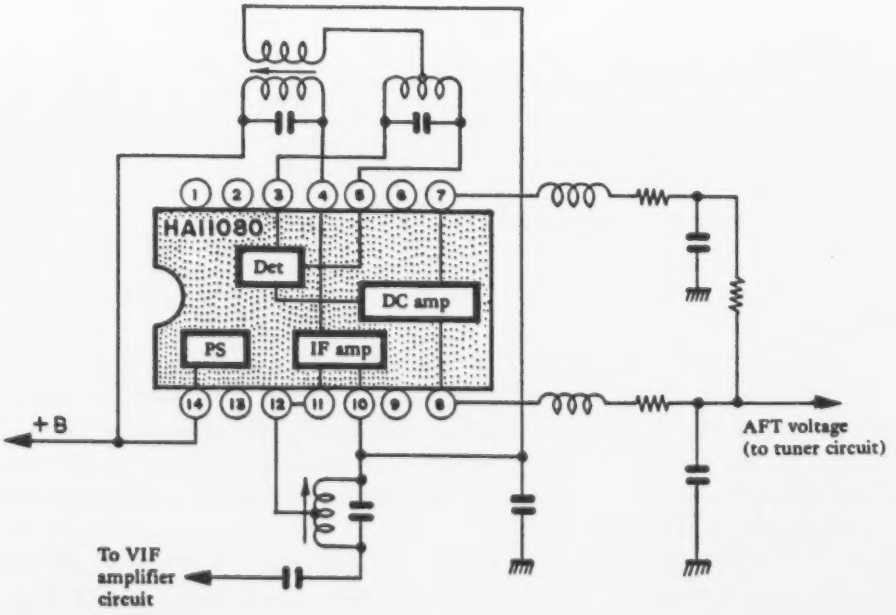


Figure 2-21
An IC AFT circuit

The electronic tuner

An electronic tuner uses a variable capacitance (varicap) diode for its tuning circuit. Channel selection is done electronically, unlike in conventional tuners where tuning is done mechanically.

The electronic tuner is tuned to different TV stations by changing the DC reverse-bias voltage across the varicap diode. This type of tuner is favourable compared with its conventional counterpart. It has no moving mechanical components and eliminates mechanical problems such as loose contact.

Electronic tuning principle. A basic electronic tuning circuit is shown in Figure 2-22. The tuner is tuned to various channels by switches SW1 to SW5. Each switch represents a TV station. When a switch is closed, a corresponding DC voltage for the station represented by the switch is supplied to the varicap diode. The supplied voltage can be adjusted and set (programmed) to a certain value by the variable resistors R3 to R7.

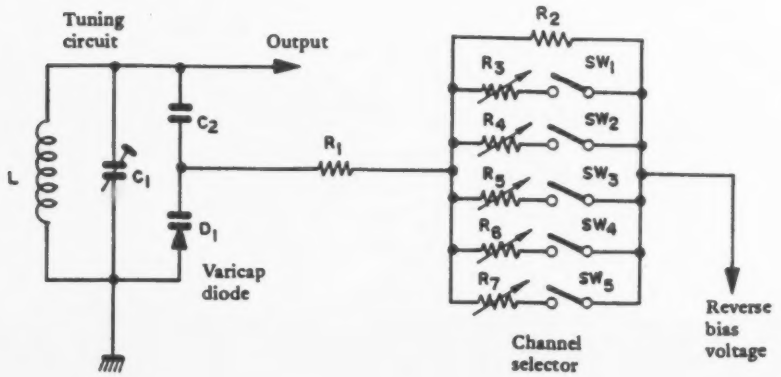


Figure 2-22
A basic electronic tuning circuit by varicap diode

The electronic VHF tuner. The variation in the capacitance of the varicap is limited, so its operation is confined to a limited band of frequencies. Because of this limitation, the varicap cannot be tuned to all the channels of the VHF band. Thus the tuning circuit in an electronic tuner is divided into two sections. One section is designed to tune in to the low-band channels (2 to 6), the other to the high-band channels (7 to 13).

Figure 2-23 shows a tuning circuit in an electronic VHF tuner. D2 switches the tuner to the low- and high-band channels. When D2 is not forward-biased, it acts as an open switch. Here the tuning circuit is formed by L1, L2, C4, D1 and C2. This is the tuning circuit for the low VHF bands. When D2 is forward-biased, the diode acts as a closed switch and connects C3 to ground. Since L2 and C4 are bypassed by C3, the tuning circuit is formed by L1, C3, D2 and C1. This circuit is used for adjusting the tuner to the high VHF bands.

Figure 2-24 shows a local oscillator circuit in an electronic VHF tuner. D1 switches the local oscillator from the low- to the high-band channels and vice versa. By the polarity of supplied voltage to D1, L1 is either shorted to ground or a part of the oscillator circuit. The frequency of the oscillator depends on the magnitude of the voltage across the varicap diode D2. Varicap diode D3 is used for automatic frequency tuning. Figure 2-25 shows a frequency-control circuit for a VHF electronic tuner.

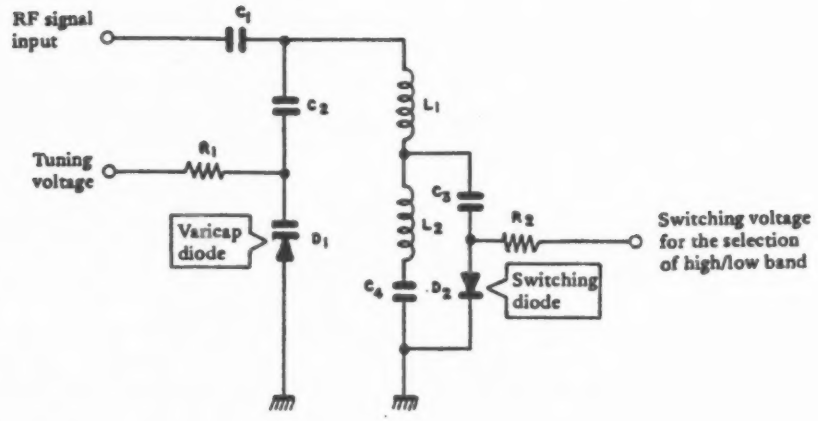


Figure 2-23
A VHF tuning circuit

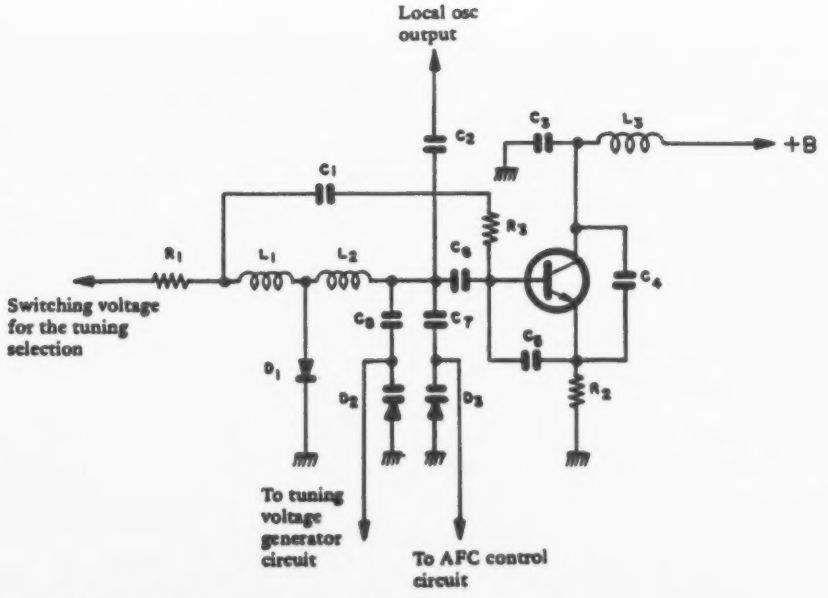


Figure 2-24
A local oscillator circuit

The electronic UHF tuner. This tuner, shown in Figure 2-26, also uses a varicap diode for its tuning circuit. The varicap is connected in series to the open end of the coaxial-cable resonant circuit. The circuit is tuned to a particular channel by supplying the proper DC reverse-bias voltage to the varicap.

A disadvantage in electronic UHF tuners is the considerable tuning loss due to the small internal resistance of the varicap diode. Hence an RF amplifier is included in UHF tuners to amplify further the output of its tuning circuit.

Matching the output impedance of an electronic UHF tuner and the input impedance of an electronic VHF tuner is difficult and complicated. So it is not practical to couple the output of a UHF tuner to the input circuit of a VHF tuner. Instead the output is coupled to the mixer circuit of the VHF tuner. The VHF tuner functions as an additional VIF amplifier stage to boost the strength of the UHF tuner output.

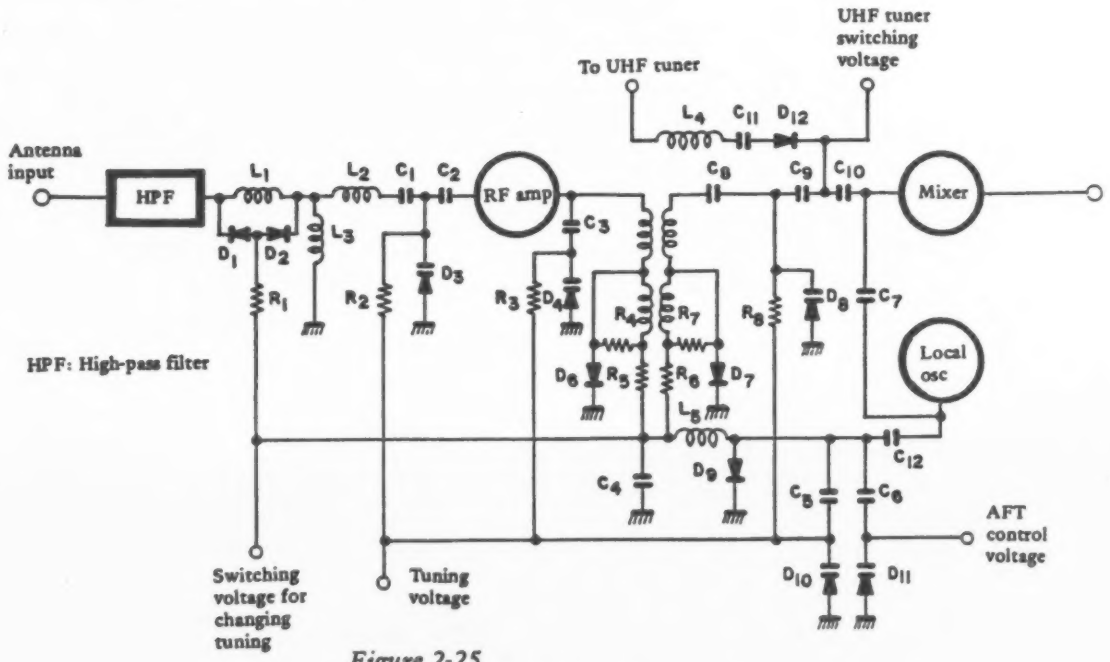


Figure 2-25
Control voltage in a VHF electronic tuner

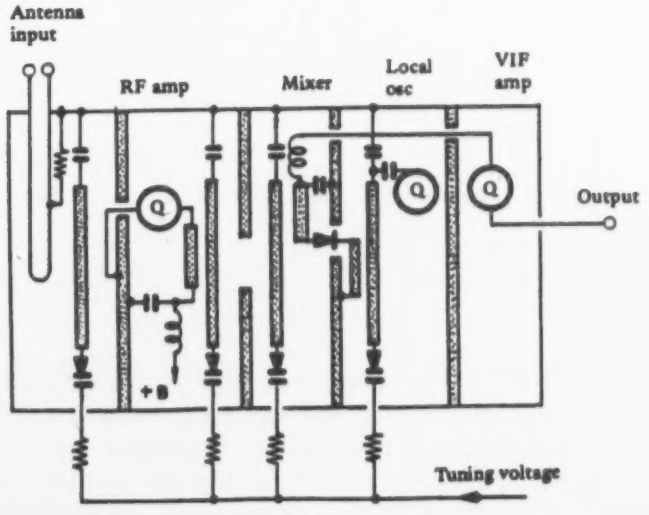


Figure 2-26
Electronic UHF tuner

Channel-selector circuit. Push-button switches are used for channel selection in an electronic tuner. The DC voltages for every TV channel are initialised. Thus, by simply pressing the proper switch, the tuner is automatically tuned to the desired TV station. Picture 2-4 shows a push-button receiver front-end panel. A functional block diagram of an electronic channel-selector circuit is shown in Figure 2-27.

Picture 2-4
A push-button receiver front-end panel

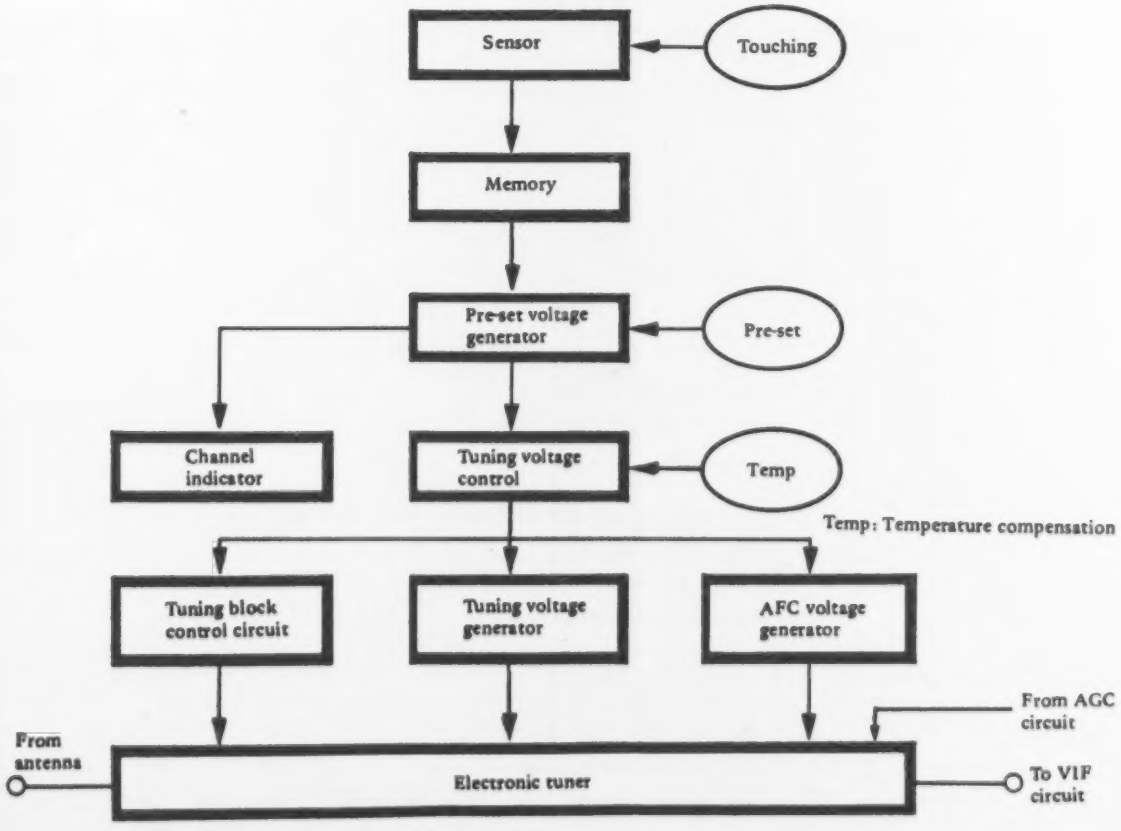


Figure 2-27
Functional block diagram of an electronic channel selector

Touch amplifier and memory circuits. A touch amplifier circuit senses the current flow from the human body when the sensor in the channel-selector panel is touched. It amplifies the current flow in our bodies to activate a memory circuit. The circuit usually makes use of a bi-stable multivibrator circuit or the difference between the ON-OFF voltage of a neon tube. Figure 2-28 shows how a touch amplifier and a memory circuit function.

Each touch amplifier and memory circuit has a corresponding selector button or sensor. When a selector button is pressed or a sensor is touched, the touch amplifier is activated and the memory circuit changes from its initial OFF state (Figure 2-28[a]) to the ON state (Figure 2-28[b]). The memory circuit maintains its ON state (Figure 2-28[c]) even after the sensor is released from touch (touch amplifier deactivated). The memory circuit remains in this state and reverts to its OFF state only after another sensor is touched. When another sensor is touched, the corresponding memory circuit is similarly set. Thus a memory circuit can be set just by momentarily touching its sensor or momentarily pressing its selector button. The memory circuit adjusts the tuning circuit of an electronic tuner to the desired station.

Tuning voltage generator circuit. Figure 2-29 shows a simple tuning voltage generator circuit. Switches SW1 to SWn are the equivalent memory circuits. Variable resistors VR1 to VRn are registers assigned to each switch for pre-setting or programming the voltages of every TV station.

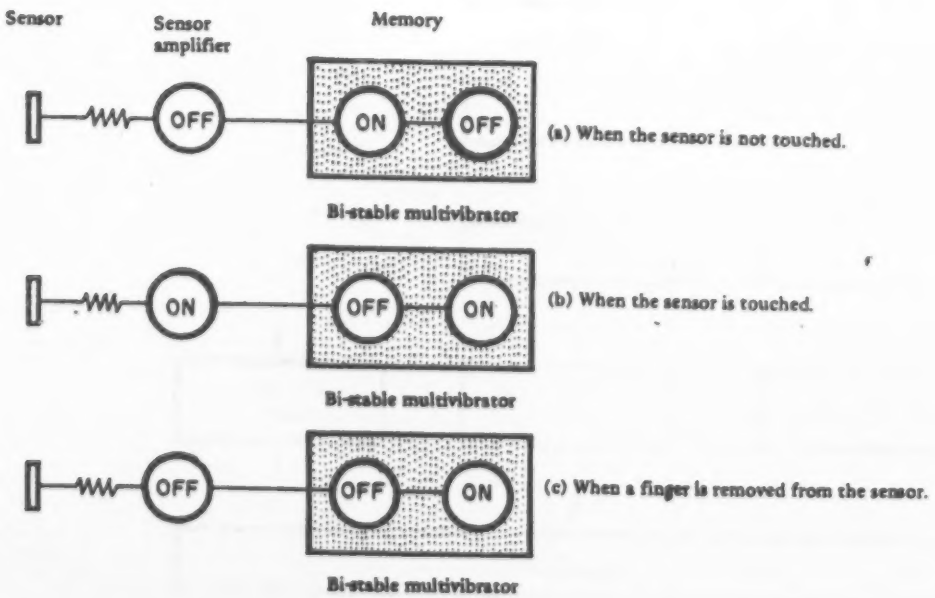


Figure 2-28
Function of a touch amplifier and a memory circuit

When the sensor of the memory circuit represented by SW1 is touched, SW1 closes. Initially, before SW1 closes, the cathode voltage of D1 is equal to the B+ voltage. When SW1 closes, a voltage drop is developed across VR1. Consequently the cathode voltage of D1 decreases. VR1 is set such that D1 is forward-biased when SW1 is closed. When D1 is forward-biased, the anode voltage becomes equal to the cathode voltage (actually, plus the junction voltage but this is negligible), which is pre-programmed by VR1. However, slight variations in the internal resistance of the diode due to changes in the surrounding temperature cause a slight change in the anode voltage. This results in a slight detuning of the circuit. To compensate, a stable current-supply circuit using a temperature-compensating diode Da is included. Diodes D1 to Dn have the same electrical characteristics.

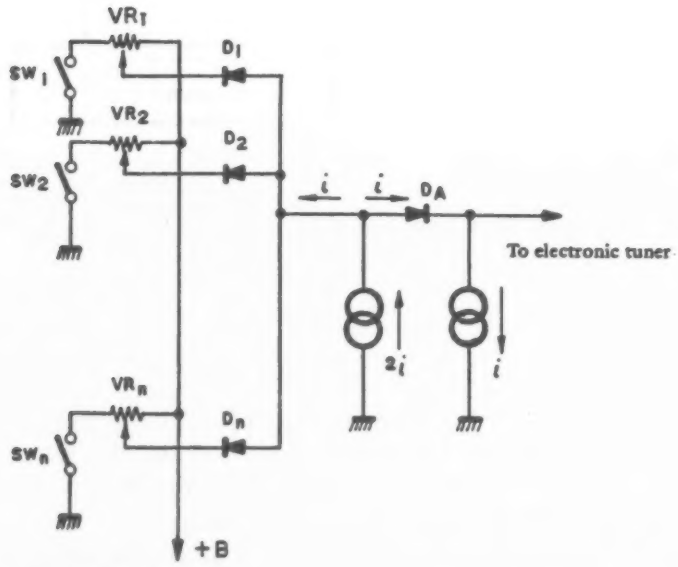


Figure 2-29
Tuning voltage generator circuit

Switching circuit for VHF and UHF bands. Figure 2-30 shows a circuit used in switching an electronic tuner from the VHF to the UHF bands and vice versa. The transistors function as switches.

For the high VHF bands, the memory circuit supplies a positive voltage to the base of Q1. This turns on Q1, and the voltage at terminal (B) of the electronic tuner becomes approximately zero. In this case, D1 is forward-biased and Q3 is turned on. So the B+ voltage is supplied to terminal (C). On the other hand, D3 is reverse-biased and Q4 is cut off, leaving terminal (D) floating. Q2 is also cut off, so the B+ voltage is also supplied to terminal (A).

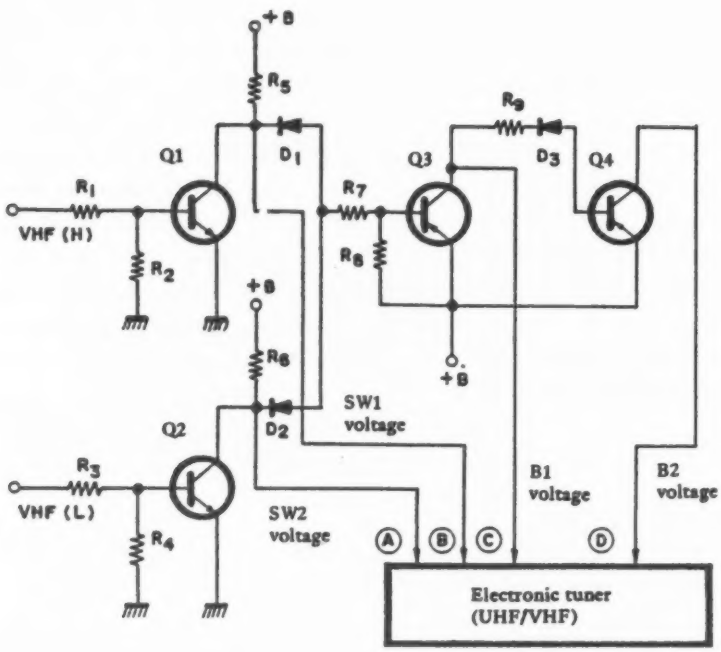


Figure 2-30
Tuning block switching circuit

For the low VHF bands, the memory circuit supplies a negative voltage to the base of Q2. This turns on Q2, and terminals (A) and (D) become approximately equal to zero bolts. Furthermore, Q3 is ON and Q1 is OFF, so the voltages at terminals (B) and (C) are equal to the B+ voltage.

For the UHF bands, Q1 and Q2 are cut off, so the B+ voltage is supplied to terminals (A) and (B). Q3 is also cut off, so terminal (C) is floating and Q4 is switched on, and the B+ voltage is supplied to terminal (D).

To sum up: the electronic tuner can be switched to the VHF and UHF bands by supplying control voltage to Q1 and Q2. By doing so, the voltages at terminals (A), (B), (C) and (D) are set to the proper combinations to switch the tuner to the desired TV broadcast band.

AFT-control voltage. The electronic tuner is affected if the AFT signal voltage is supplied to it during channel selection. Thus one must disable the AFT circuit during the selection.

Methods of disabling the AFT circuit. There are three ways to disable the AFT circuit during the channel selection. These are 1) using the pulses generated before the glow of a neon tube used for the channel indicator; 2) using the pulses tapped from the sensor amplifier or memory circuit; and 3) setting the tuning voltage to a low value to decrease the local oscillator frequency.

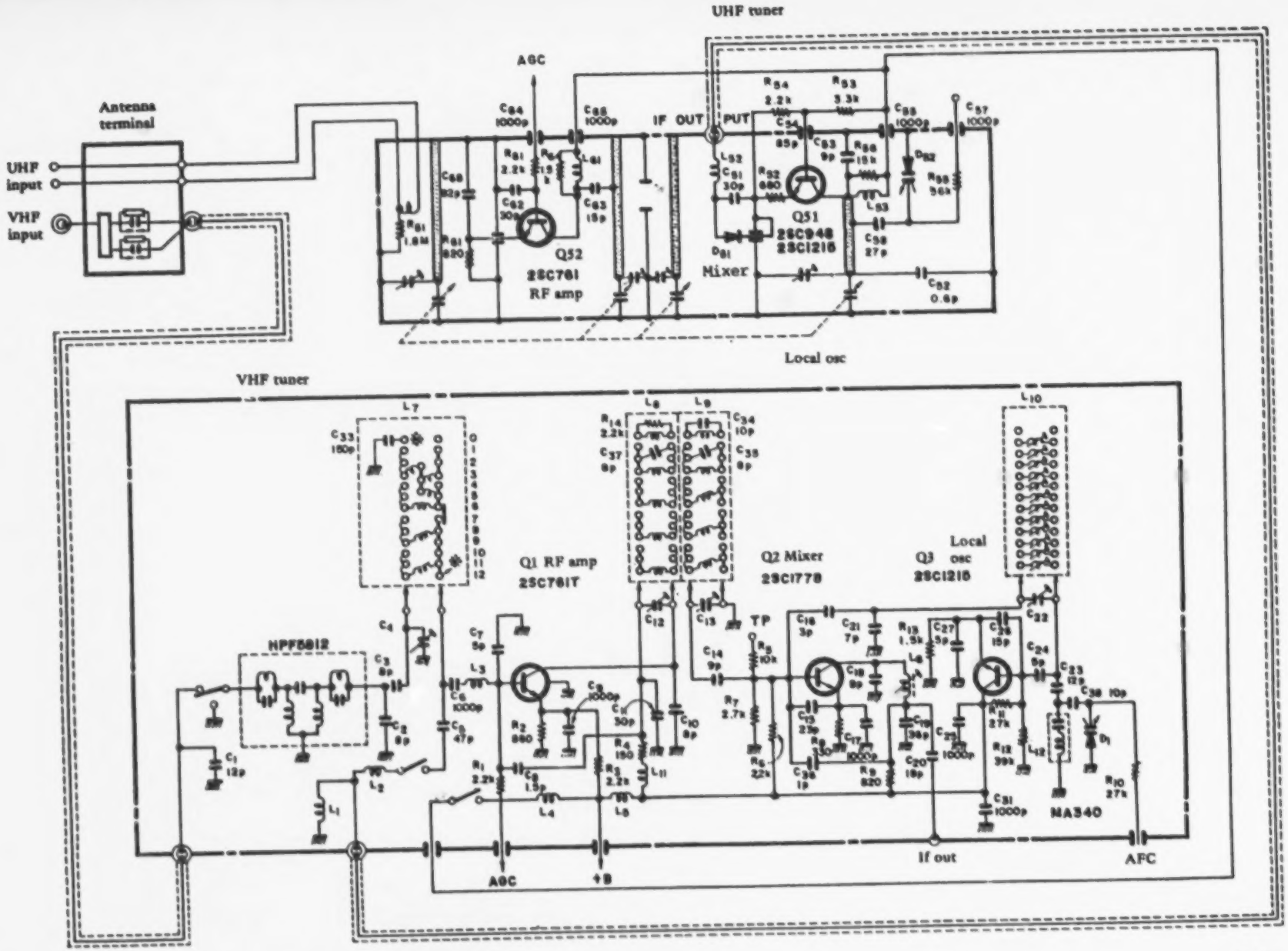


Figure 2-31
An actual tuner circuit

Remote-control apparatus

The ultrasonic and the infrared frequencies are used for remote-control purposes.

Ultrasonic remote control. The frequency of the ultrasound used for remote-control purposes ranges from 30 to 50 kHz. Every remote-control function is assigned to different frequencies. A special kind of ultrasound is used to avoid interference with the electronic tuner. An electronic oscillator is generally used to generate ultrasounds for remote control.

Infrared remote control. A light-emitting diode is used to transmit infrared signals from the control box. A photo-diode in the TV set receives the infrared signal and converts it to a control signal.

Examples of actual tuner circuits

Figure 2-31 shows an actual TV tuner circuit. The VHF tuner is a disk-turret type and the UHF tuner has its own RF amplifier.

In a VHF mode, RF signals from the antenna are coupled to the input tuning circuit. The tuning circuit passes the RF signal of the tuned-in station and rejects the rest. The desired RF signal is then fed to the RF amplifier circuit. L8 and L9 electromagnetically couple the amplified RF signal to the mixer circuit.

C16 couples the local oscillator signal to the mixer circuit, where the RF signal and the oscillator signal are heterodyned. The output of the mixer circuit is the VIF signal. This signal is coupled to the succeeding VIF circuits.

In a UHF mode the RF signal is fed to the mixer diode (D51) after being amplified by the UHF RF amplifier. The VIF signal at the output of the UHF mixer is supplied to the VHF tuner through a coaxial cable. The mixer and the RF amplifier of the VHF tuner amplify the VIF signals from the UHF tuner to boost its strength before it is coupled to the VIF circuits.

Video intermediate frequency (VIF) amplifier circuit

Structure and function of the VIF amplifier circuit

The VIF amplifier circuit supplies most of the gain of the whole block of the video signal reproduction circuit. The quality of the picture reproduced on the screen is directly affected by the selectivity of the VIF amplifier circuit.

As shown in Figure 2-32(a), the vestigial sideband transmission is used in sending the TV RF signal. If the VIF amplifier circuit is designed to have a flat frequency response within the band of the VIF signal like the tuner [Figure 2-32(b)], the video-detector output will have a response, shown in (c). Note that the lower-frequency signal components are given more amplification.

To get a constant level for the signals at the output of the video detector [Figure 2-32(e)], the VIF amplifier circuit should be designed to have the frequency response shown in Figure 2-32(d).

Thus in the design of the VIF amplifier circuit, a special selectivity response is to be considered for vestigial sideband-transmitted signals. The overall gain of the VIF amplifier stages should be around 70 dB for a sufficient signal level at the output of the VIF amplifier stages.

Intermediate frequency (IF)

The frequency for the IF signal in TV receivers is chosen to avoid possible interference with other circuits such as the local oscillator circuit. Receivers made in the USA use the IF band 41-47 MHz. TV receivers in Europe and the PAL region use the 30 MHz band. In Japan the IF signal is in the 50 MHz band.

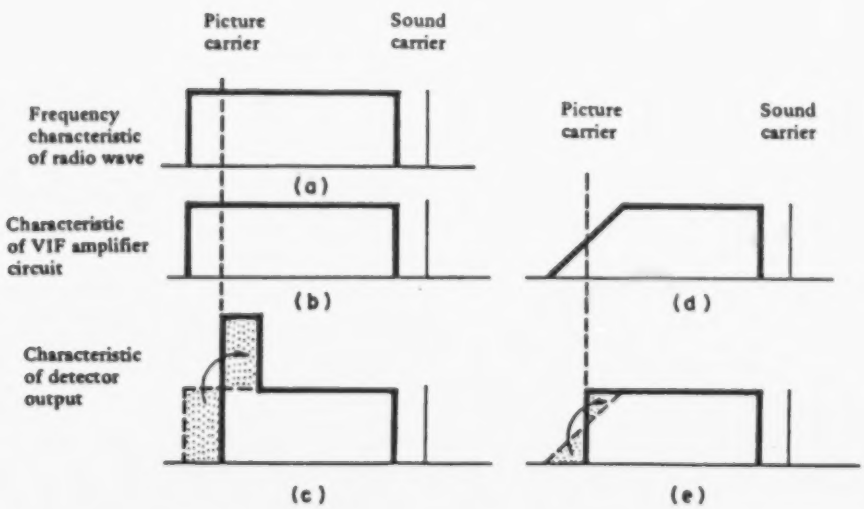


Figure 2-32
Relationship between the selectivity of a TV receiver and the frequency response of the detector output

The local oscillator frequency for each TV station is chosen to be higher than the RF signal carrier frequency. Thus the order of the video and sound carriers in the IF signal is reverse compared with the order of the video and sound carriers in the RF signal. The video carrier in the IF signal is 45.75 MHz and the sound carrier is 41.25 MHz for receivers made in the USA. The video and sound carriers are 39.50 MHz and 33.50 MHz in Europe and PAL.

The AGC bias is normally applied to the first IF stage because the gain can be controlled since the signal is still low. The three VIF stages are stagger-tuned to cover the 4 MHz bandwidth.

Selectivity response of the VIF circuit

Although the selectivity response of a TV receiver is determined by the total selectivity of the tuner and VIF circuits, the overall response of a TV receiver is more dependent on the response of the VIF circuit. The VIF amplifier should have a bandwidth of 4 MHz (video bandwidth). However, if the VIF circuit is designed to have this bandwidth, the sidebands corresponding to the low video frequencies of the picture signal of the upper adjacent channel and the sound signal of the lower adjacent channel can interfere with the picture signal of the desired station. This interference causes the windshield-wiper effect.

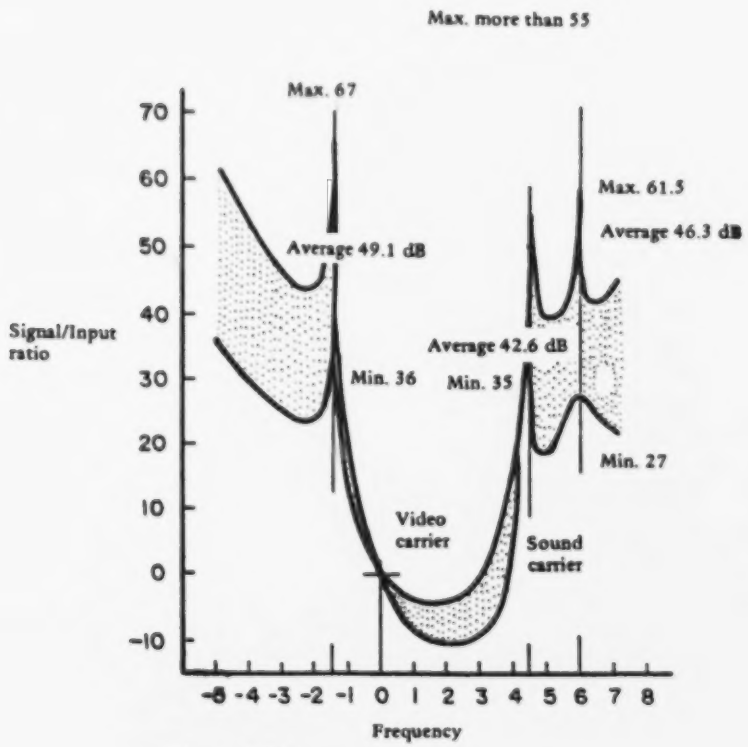


Figure 2-33
Selectivity of a VIF amplifier circuit

Considering vestigial sideband transmission, interference is avoided by designing a VIF amplifier with a selectivity response, shown in Figure 2-33. The video-carrier signal is located -6 dB from the peak of the VIF characteristic curve. The sound-carrier signal is attenuated by more than 40 dB with respect to the level of the video carrier to avoid interference with the video-carrier signal (4.5 MHz interference) and the colour subcarrier signal (920 kHz interference).

To avoid the windshield-wiper effect, the sound carrier of the lower adjacent channel and the picture carrier of the upper adjacent channel are attenuated by 40 to 50 dB with respect to the level of the desired picture-carrier signal.

The colour subcarrier signal (3.58 MHz) is located at -6 dB from the peak of the video-carrier signal. Thus at the detector output, the level of the colour subcarrier signal is uneven. This distortion is compensated by the special transformer in the input circuit of the bandpass amplifier circuit.

VIF amplifier circuit

The VIF amplifier circuit is usually formed by three to four tuned amplifier stages in order to get a 70 dB gain and the necessary bandwidth. Figure 2-34 shows a variety of the tuning circuits used in the VIF amplifier circuit.

The necessary bandwidth for the VIF circuit is obtained in solid-state receivers by using combinations of single- and double-tuned circuits. The first stage is usually a wide-band single-tuned amplifier circuit because the AGC voltage is applied to the first stage of the VIF circuit. A change in the AGC voltage affects the input and output capacitance of the transistor, and the input and output impedance of the circuit. This causes a drift in the VIF signal or a change in the bandwidth of the circuit. With a wide-band amplifier, this is not much of a problem. For VIF amplifier IC circuits, the IC functions as the wide-band amplifier. The tuning circuit is placed at the input and the output of the IC circuit to get the required frequency response.

Single-tuned circuit. There are many types of single-tuned circuits, as shown in Figure 2-35. The type used in the VIF circuit depends on the type of transistor or amplifier circuit used in the VIF circuit. The bandwidth of the VIF circuit depends on the quality factor Q of the tuning circuit used. The smaller the value of Q, the wider the bandwidth of the circuit.

Figure 2-36 shows examples of tuning circuits used by the ones shown in Figures 2-35(a) and (b). In these circuits the AGC voltage is applied to Q2 and Q4. The necessary bandwidth is obtained by connecting a damping resistor R2 parallel to the tuning circuit. R2 reduces the quality factor of the circuit increasing the bandwidth.

Double-tuned circuit. A double-tuned circuit has a sharper selectivity than a single-tuned circuit. Figure 2-37 shows two types of double-tuned circuits commonly used. These circuits are inductance-coupled and capacitance-coupled. The circuit in Figure 2-34 is used to get the ideal selectivity of the VIF circuit.

Figure 2-38 shows double-tuned amplifier circuits. Figure 2-38(a) is a double-tuned circuit inductively coupled by T2. Figure 2-38(b) shows another double-tuned circuit in which two single-tuned circuits (T1 and T2) are capacitively coupled by C6.

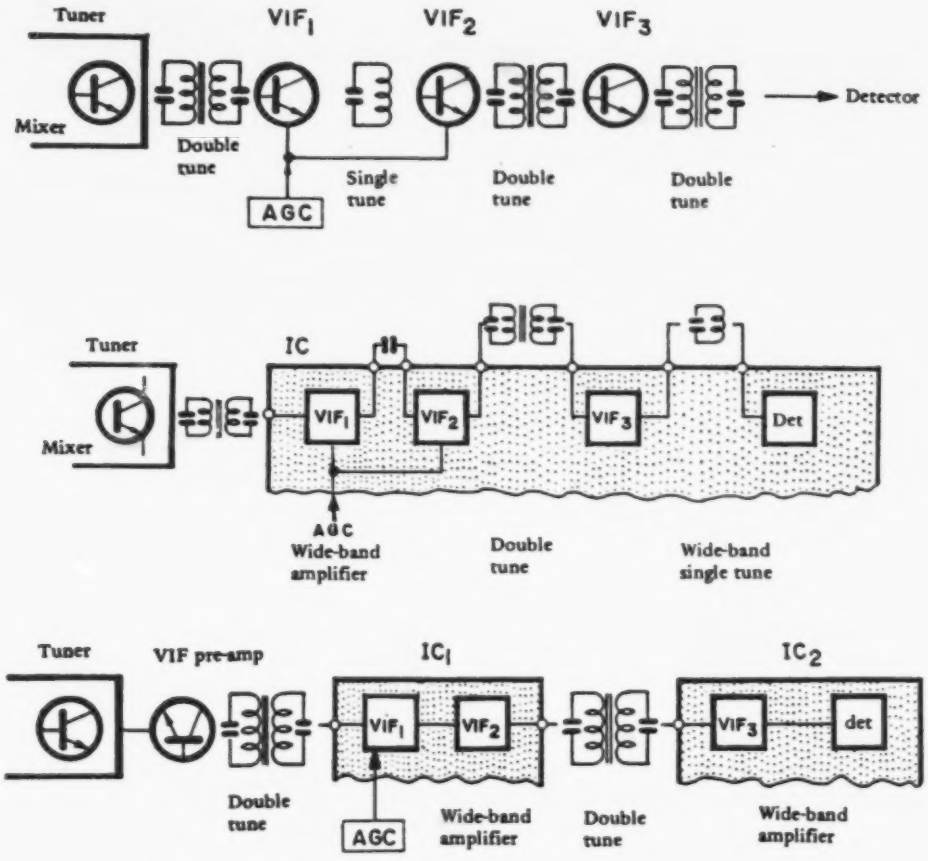


Figure 2-34
Various tuning circuits in a VIF amplifier circuit

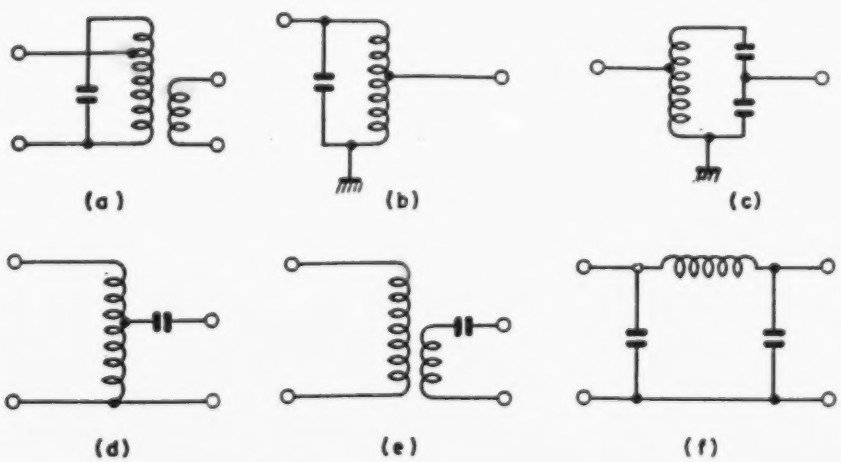


Figure 2-35
Single-tuned circuits

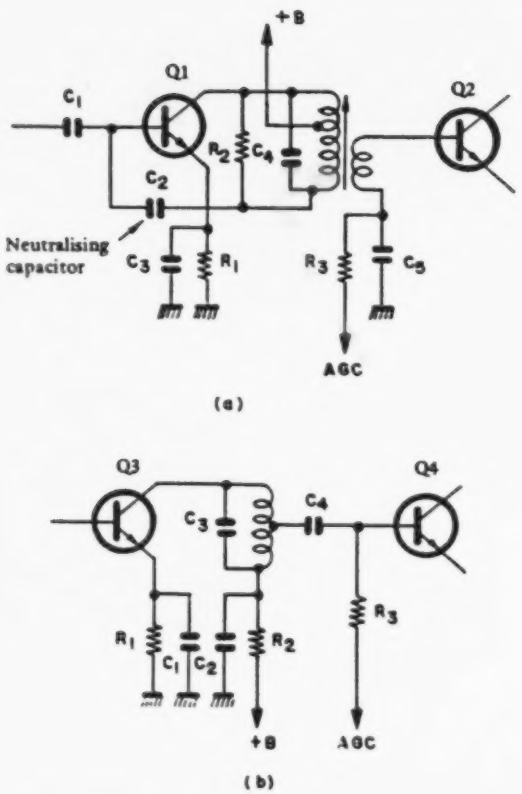


Figure 2-36
Examples of wide-band single-tuned amplifier circuits

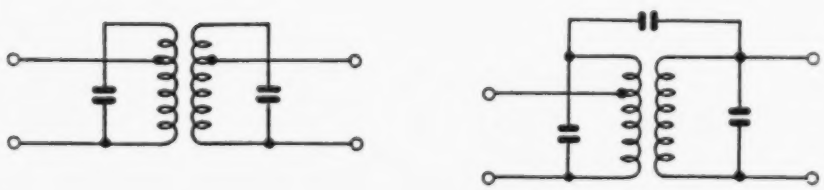


Figure 2-37
Double-tuned circuits

Figure 2-44 shows a special double-tuned circuit used to couple the output of the tuner to the input of the VIF amplifier circuit. In this circuit two independent single-tuned circuits are coupled by a low impedance.

Trap circuit

Besides the methods of getting the proper selectivity for the VIF circuit described in the section on "Selectivity Response of the VIF Circuit," trap cir-

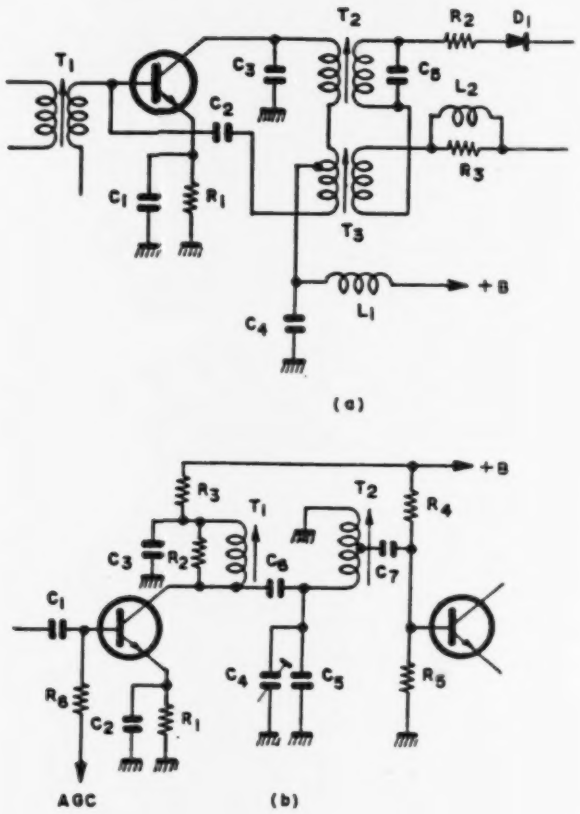


Figure 2-38
Double-tuned circuits

cuits are used to get sharper selectivities. The traps used in a VIF circuit are sound signal and adjacent channel signal traps. The trap circuits should have a high Q and a very sharp decrease in the gain around the resonance frequency. The following types of traps are commonly used in TV receiver circuits.

Capacitance-coupled trap. Figure 2-39 shows the capacitance-coupled trap circuits. A trap circuit using a simple series resonance circuit is shown in (a). This trap is usually used in circuits having a rather low impedance. It is commonly used for sound and adjacent channel signal traps.

The resonance frequency of the circuit in Figure 2-39(b) is determined by L1, C1 and C2. The resonance frequency fo (trap frequency) is given by,

$$f_o = \frac{1}{2\pi\sqrt{L_1 (C_1 + C_2)}}$$

where C1 << C2 (C1 is much less than C2)

The advantage of this trap circuit is that it can be placed anywhere in the VIF circuit without affecting the performance of the IF transformer. The coupling factor can be modified by changing the value of C1.

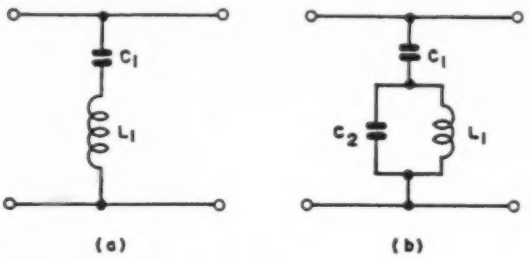


Figure 2-39
Capacitance-coupling traps

The bridge trap. Figure 2-40(a) shows a bridge-trap circuit. The resonant frequency is determined by the values of L, C1 and C2. The circuit shown in (b) is a block representation of the circuit in (a). Figure 2-40(c) is a further generalisation of a bridge-trap circuit. When R is set equal to the magnitude of Z3, the circuit between points (2) and (E) in (c) behaves as a short to resonant frequency signals. Thus theoretically, an infinite attenuation can be obtained for resonant signals.

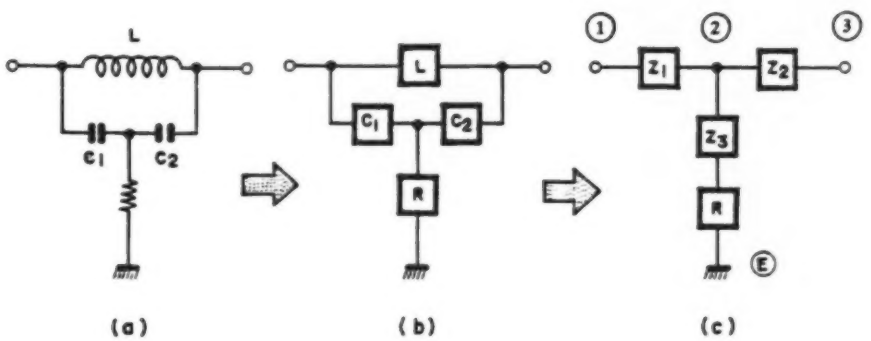


Figure 2-40
Bridge-trap circuit

The M-coupling bridge trap. This trap is used between the last stage of the VIF amplifier circuit and the video detector, as shown in Figure 2-41. A loose-coupled L4 and a tight-coupled L3 with respect to input signal are connected in series. But they are wound in directions to induce opposing voltages.

By adjusting R1, the voltages across C3 and Co can be set equal at the resonance frequency. Thus at resonance, a sharp attenuation can be obtained by the opposing effects of L3 and L4.

The bifiler trap. Figure 2-42(a) shows the principle of a bifiler trap. Coils L1 and L2 are bifiler coils, thus having the same inductance. By setting the coupling factor to 1, e1 becomes equal to e2 (e1 = e2).

But as shown in the figure, by reversing the connection of L2, e1 becomes equal to - e2 (e1 = - e2). Connecting a parallel resonance circuit formed by L3 and C1, the circuit becomes inductive at lower frequencies. The equivalent inductance varies with the resonance frequency.

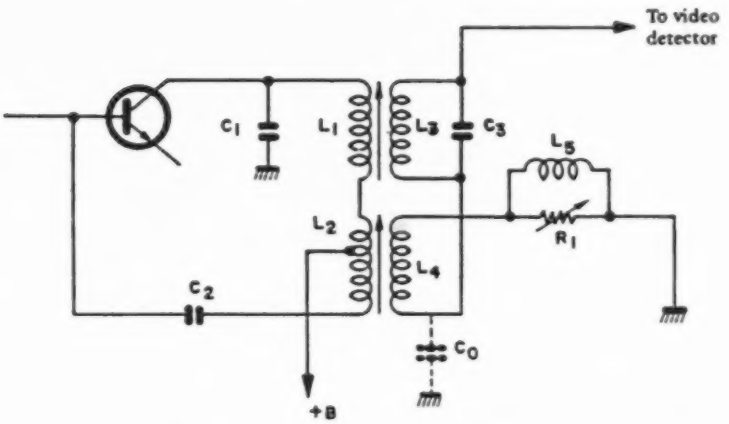


Figure 2-41
M-coupled bridge-trap circuit

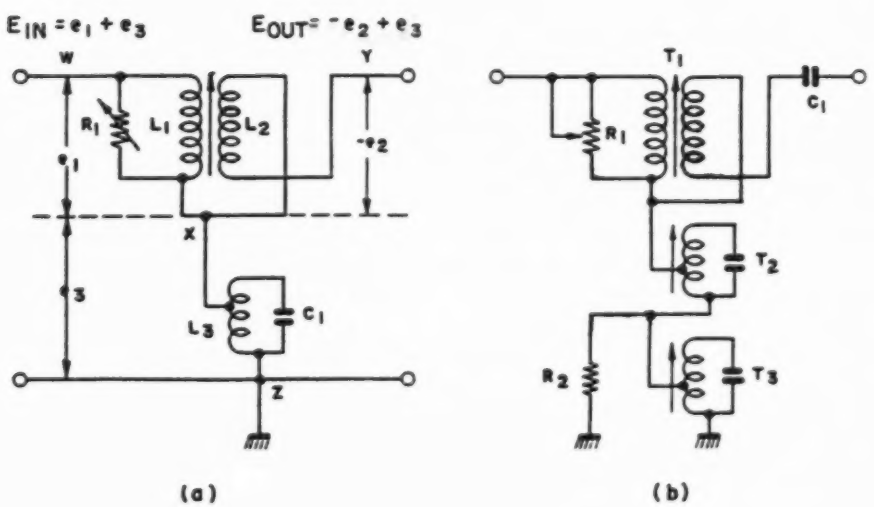


Figure 2-42
Bifiler T-trap circuit

At the resonance frequency, R1 can be adjusted to a value equal to the circuit's impedance formed by L3 and C1. This also sets e1 equal to e3 (e1 = e3) and - e2 becomes equal to e3 (- e2 = e3). Thus the output (e2 + e3) becomes zero at the resonance frequency. However, because of the stray capacitance of the circuit, the attenuation at the resonance frequency is not infinite. In actual circuits the attenuation is roughly 40 dB.

Figure (b) shows an application of the bifiler-trap circuit. Transformers T1 and T2, T1 and T3 form pairs and function as adjacent channel-signal and sound-signal trap circuits, respectively. A change in R1 is reflected to the two traps but mainly functions to adjust the sound-signal attenuation. This attenuation is controlled because the sound signal is taken out from the succeeding stages.

Other types of traps. For some other types of traps, series-coupled traps and piezonators are used. Figure 2-43 shows other kinds of traps. The piezonator has a resonance circuit formed by its own LCR and has a stable function without adjustment.

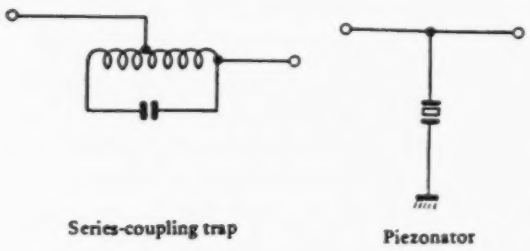


Figure 2-43
Other types of trap circuits

Coupling circuit of tuner and video-amplifier circuit

The output of the tuner and the VIF amplifier circuit are linked by a coaxial cable. A coaxial cable, however, would be rather long, so a coupling circuit such as that shown in Figure 2-44 is generally used. This coupling circuit uses a double-tuned capacitance-coupled circuit formed by C3, C4 and the static capacitance (Co) of the coaxial cable. With this coupling arrangement, the local oscillator signal which appears at the output of the mixer circuit will be blocked by the filter circuit formed by L1, C1 and C2.

Types of actual VIF circuit used in a TV receiver

VIF amplifier circuit in a solid-state TV. Figure 2-45 shows a three-stage transistorised VIF amplifier circuit. The signal from the tuner is coupled to the circuit by a double-tuned circuit formed by T1 and T2 (IF transformers). The coupled signal is then fed to the base circuit of Q1, where three traps are located. These traps are the lower-adjacent channel sound trap (47.25 MHz), sound trap (41.25 MHz) and the upper-adjacent channel sound trap (39.75 MHz).

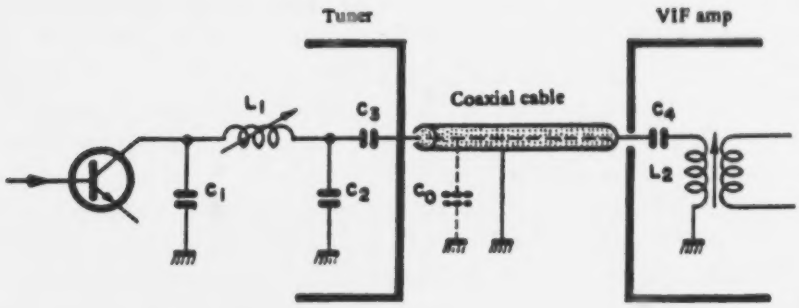


Figure 2-44
Coupling to a tuner circuit

Transistors Q1 and Q2 are coupled by a single-tuned circuit formed by T3; Q2 and Q3 are coupled by T4, which also is a single-tuned circuit. The AGC-control voltage, which controls the gain of Q1 and Q2, is supplied to the base of Q2.

Q3 supplies the IF video signal to the video detector through T5, which is a double-tuned circuit. Q3 should have a good linearity to prevent distorted signals coupled to the detector. Note that the selectivity of the VIF amplifier circuit depends mainly on the selectivity of the double-tuned circuits formed by T1, T2 and T3, T4. The 4.5 MHz sound signal is taken out from the primary of T5 and then supplied to the SIF amplifier circuit. T5 is also a part of the M-coupled bridge-trap circuit, which traps the sound-signal carrier, preventing it from going to the input of the video detector.

VIF IC amplifier circuit. Figure 2-46 shows a typical VIF amplifier circuit consisting of ICs. In actual VIF amplifier circuits, ICs are used for wide-band amplification. Tuning and trap circuits are placed at the input and output circuits of the ICs to meet the bandwidth requirement of the amplifier circuit, since inductive elements are difficult to include inside IC circuits.

The VIF signal from the tuner passes through the two bridge-trap circuits [the piezonator (X1) and the double-tuned circuit (T1)] before being fed to IC1. The signal is amplified by the wide-band IC amplifier, whose gain is controlled by the AGC. The amplified VIF signal is taken out from the tuning circuit formed by T2 and T3, with the overall frequency response adjusted. This signal is further amplified by IC2 before being fed to the video-detector circuit.

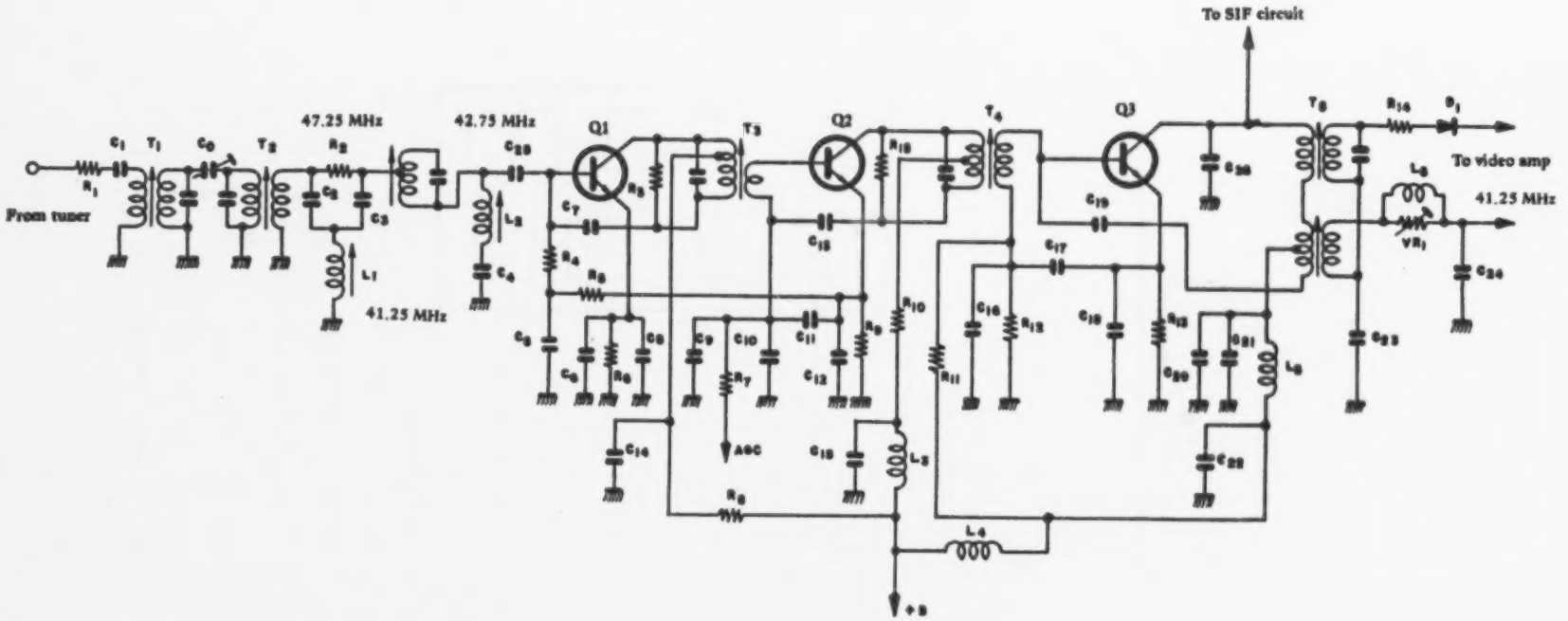


Figure 2-45
A VIF amplifier circuit

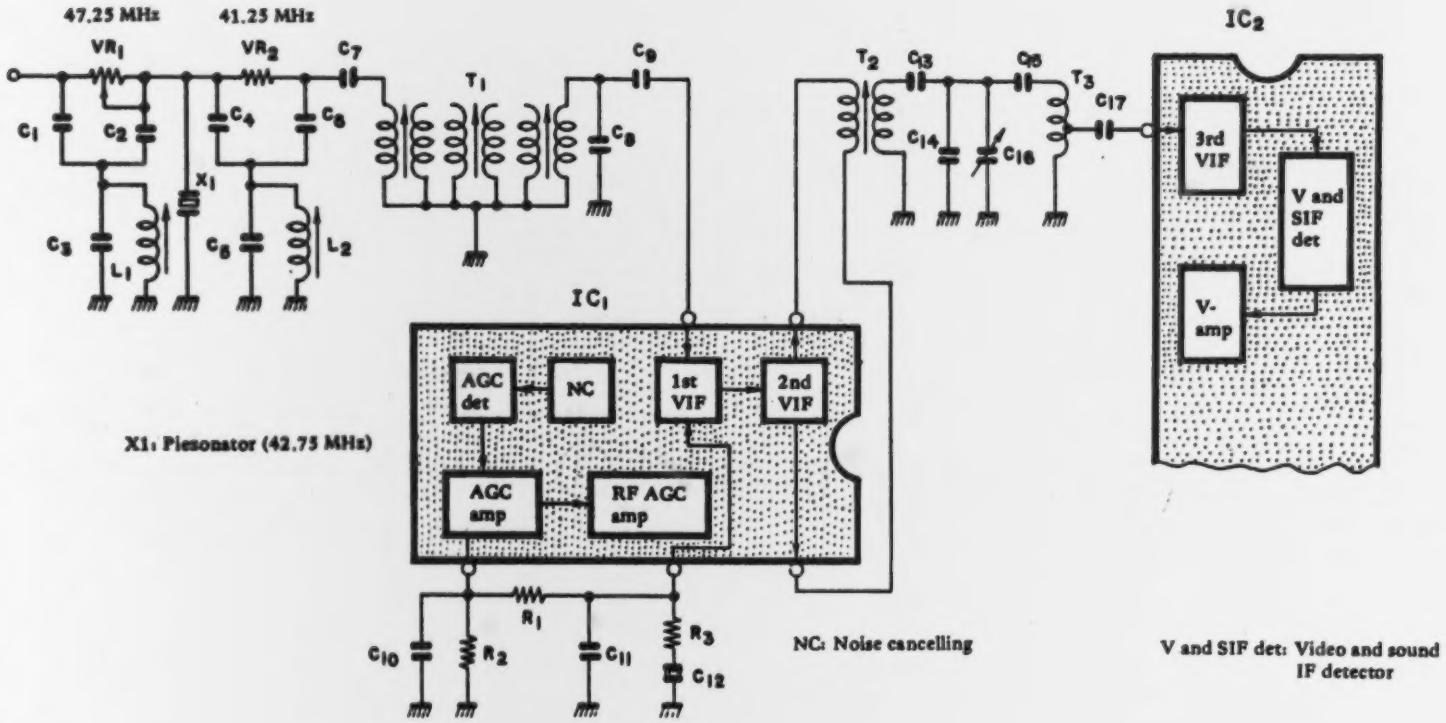


Figure 2-46
An IC VIF circuit

Video-detector circuit

The modulated TV IF signal amplified by the VIF amplifier circuit is detected by the video-detector circuit. The output of the detector is the composite video signal.

To get a video signal with a low distortion and a high fidelity, a diode with a low distortion and good linearity or an LLD (low-level detector) circuit should be used for the video-detector circuit. The load at the output of the video detector has a low-resistance resistor to provide a wider frequency response.

Video-detector diode circuit

The principle of a video-detector circuit with a diode will be explained, using the video-detector circuit shown in Figure 2-47. The polarity of the composite video signal at the detector output depends on the orientation of the diode in the detector circuit. A positive and negative polarity composite video signal is taken out in the circuits shown in Figure 2-47(a) and Figure 2-47(b), respectively. The number of the stages used in the video amplifier circuit and the kind of drive used for the CRT (cathode- or grid-drive) determine the polarity of the video signal to be taken out from the output of the detector.

An example of a diode-detector circuit is shown in Figure 2-48. The VIF amplifier output is coupled to the detector circuit by T1. Diode D1 detects the modulated signal, and a negative polarity composite video signal is taken out across R5. The total parallel resistance consisting of R2 and R5 is the load resistance of the video detector. A small load resistance is connected to yield a wider frequency response.

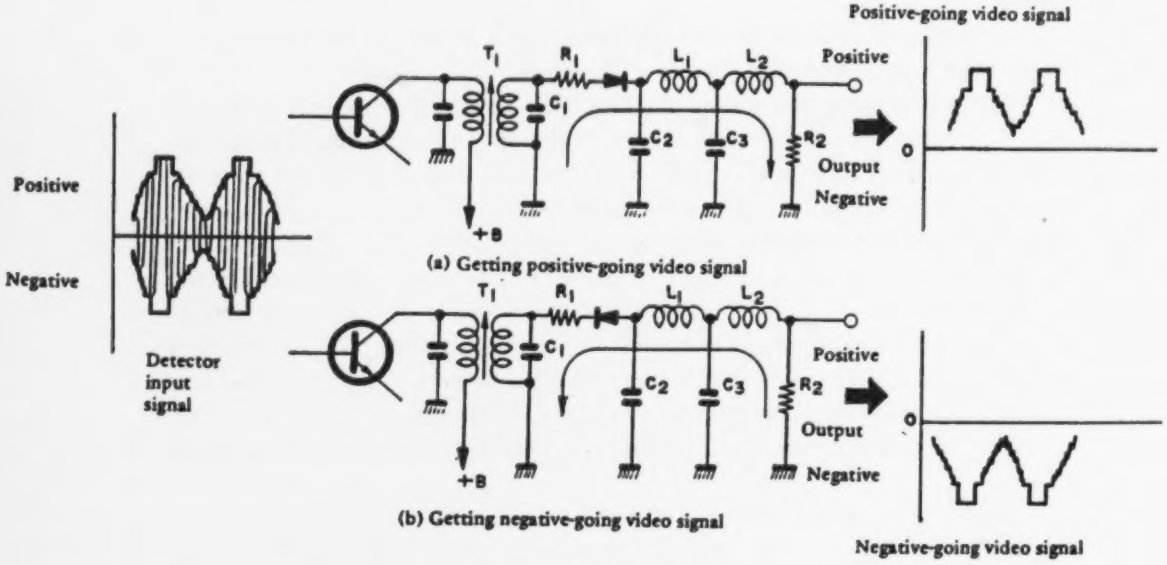


Figure 2-47
Video-detector circuit

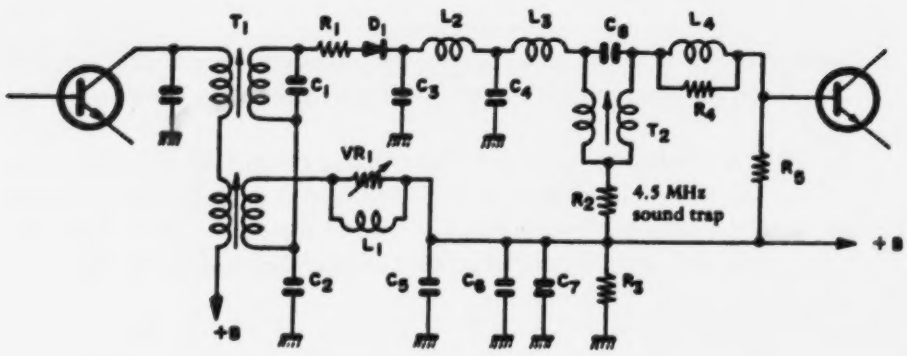


Figure 2-48
A diode video-detector circuit

A bridge trap formed by C8, T2 and R2 is placed at the detector's output. This trap is tuned to the sound carrier frequency (4.5 MHz) to prevent it from beating with the picture signal. A low-pass filter circuit formed by L2, L3, L4, C3 and C4 prevents the VIF sound-signal component at the output from going into the video amplifier circuit.

Low-level video-detector circuit (LLD)

When an IC is used as a VIF amplifier, the use of an ordinary diode detector will decrease the quality of the picture. A different kind of detector circuit is needed.

An ordinary detector diode requires an input from 2 to 3 Vp-p to get an output with a good linearity and a low distortion.

The requirement arises from the non-linear characteristic of the input and output response curve of the diode around the cut-off or threshold point. Because of the small gain in IC amplifier circuits, the output voltage of a VIF IC amplifier is not enough to drive the diode in the linear region to get a linear and a low distorted signal at the detector output. Thus if an ordinary diode-detector circuit is used, a transistor amplifier circuit is needed to amplify the output of the VIF IC amplifier. However, the addition of a transistor circuit in a VIF IC amplifier circuit complicates the design of the VIF circuit. So a different kind of video-detector circuit is needed to detect the VIF signal amplified by IC amplifiers. This circuit is the LLD (low-level detector) circuit, which yields a strong, linear and a low distorted output even though the input signal is weak.

Structure of an LLD circuit. Figure 2-49 shows a block diagram of an LLD circuit. It consists of an amplitude-limiter amplifier circuit and a dual-balanced detector circuit.

How the LLD circuit works. Figure 2-50 shows an LLD IC circuit. Figure (a) shows the amplitude-limiter amplifier section. This circuit levels the amplitude of the video carrier signal. Q10 and Q11 form a differential amplifier cir-

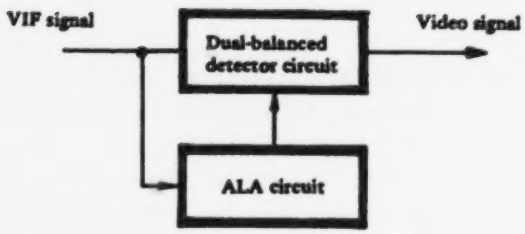


Figure 2-49
Block diagram of an LLD circuit

cuit. This circuit clips the amplitude variations in the IF signal, producing a 45.75 MHz signal carrier, and supplies this signal to the LC circuit. Diodes D1 and D2 clip the peak part of the carrier signal supplied to the LC circuit, producing a square wave.

Figure (b) shows a dual-balanced detector circuit. The differential amplifier circuit formed by Q3 and Q6 amplifies the VIF signal fed to the base of Q3. The amplified signal is fed to the emitter circuits of the differential amplifiers Q1Q2 and Q4Q5. On the other hand, the square-wave signal from the output of the amplitude-limiter amplifier is supplied to the base-circuits of the dif-

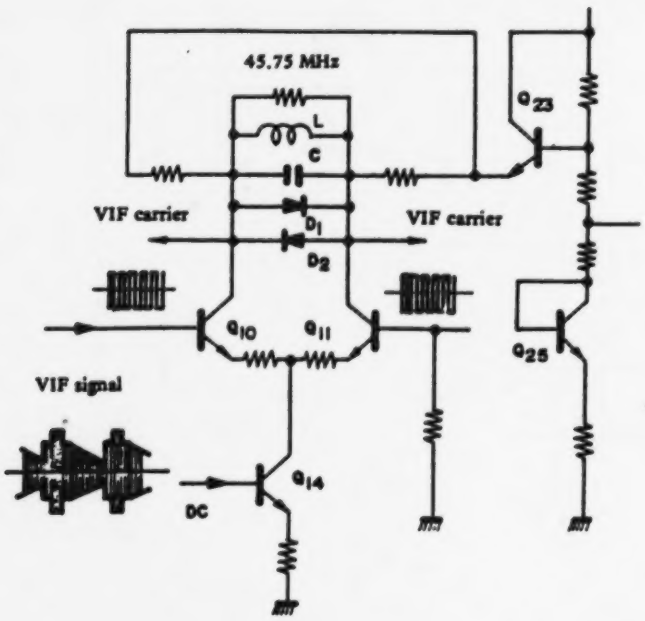


Figure 2-50(a)
Amplitude-limiter amplifier (ALA) circuit, an example of an LLD circuit

ferential amplifiers Q1Q2 and Q4Q5. This signal switches on the two differential amplifiers alternately.

When the signal shown in Figure 2-51(a) is supplied to the emitter circuit of Q1Q2 and the signal shown in Figure 2-51(b) is supplied to the base of Q1, the signal in Figure 2-51(c) is then produced at the collector of Q1. On the other hand, when signals in Figures 2-51(d) and (e) are supplied to the emitter circuit of Q4Q5 and to the base of Q5, respectively, the signal in Figure 2-51(f) will be produced at the collector of Q5. Therefore the signals shown in (c) and (f) are generated at alternate half-cycles across R1. The signal in Figure (g) is the composite signal, consisting of the signals shown in (c) and (f), generated across the output resistor R1. The polarity of the video signal at the output is positive.

The signals produced at the collector of Q2 and Q4 are just the negative of the signals produced at the collector of Q1 and Q2, respectively. Thus a negative composite video signal is generated across R2.

In short, the VIF signal from the VIF IC amplifier output is amplified first by the differential amplifier Q3Q6, then detected by the two differential amplifiers Q1Q2 and Q4Q5. Thus, even if the input IF signal is weak, a strong composite video signal with good linearity and low distortion can be taken across the output of an LLD circuit.

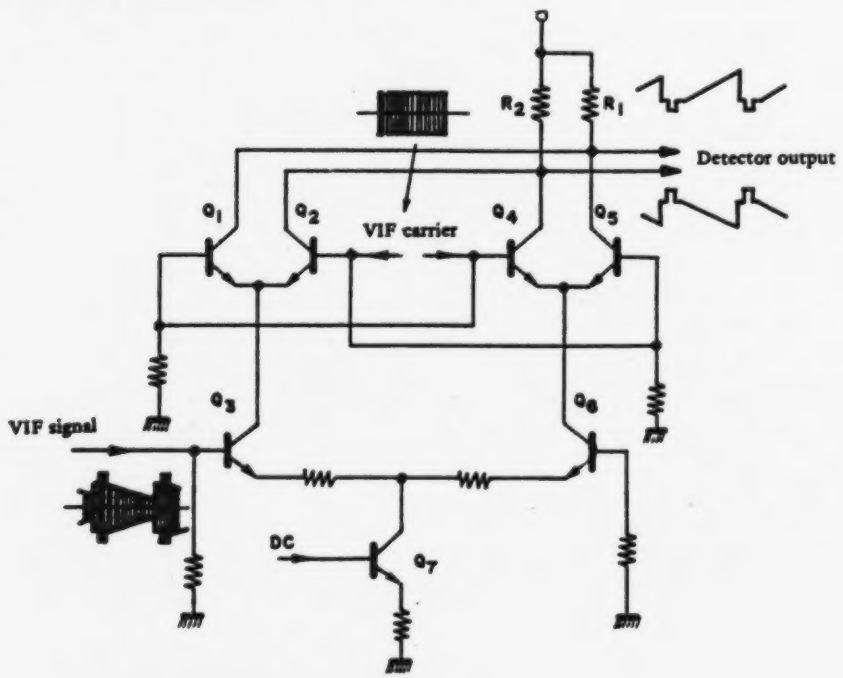


Figure 2-50(b)
Dual-balanced detector circuit, an example of an LLD circuit

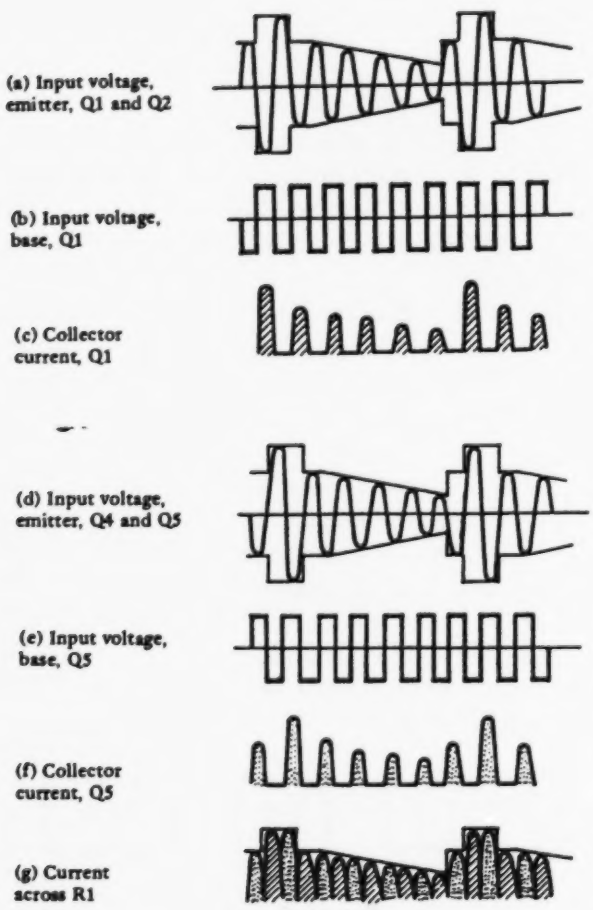

(a) Input voltage, emitter, Q1 and Q2
(b) Input voltage, base, Q1
(c) Collector current, Q1
(d) Input voltage, emitter, Q4 and Q5
(e) Input voltage, base, Q5
(f) Collector current, Q5
(g) Current across R1

Figure 2-51
Functional wave-form of a dual-balanced detector circuit

AGC circuit

AGC function

The function of the AGC is to vary the gain of IF and RF circuits in accordance with the strength of the incoming signals. The receiver should have higher gain when the incoming TV RF signal is weak and should have a lower gain when the incoming signal is strong. Thus the AGC maintains a relatively constant level at the video-detector output regardless of variations in the incoming signal strength. A constant output in the video detector is necessary for a constant contrast in the picture on the screen.

Figure 2-52 shows a block diagram of an AGC circuit. The AGC bias is a DC voltage whose value is determined by the strength of the incoming signals. The level of the video-detector output indicates the strength of the RF TV signal. The AGC voltage is supplied to the VIF amplifier and to the RF circuit in the tuner to vary their gain.

When the TV signal is strong, the AGC voltage reduces the gain of the RF amplifier circuit and maintains the gain of the VIF amplifier circuit. This prevents generation of cross-modulation interference in the RF circuit. But when the incoming signal is weak, the AGC increases the gain of the VIF amplifier and maintains the gain of the RF amplifier. The gain of the RF stage is not varied to maintain the quality of the signal-to-noise ratio to minimise noise generated in the mixer, because the incoming signal is weak.

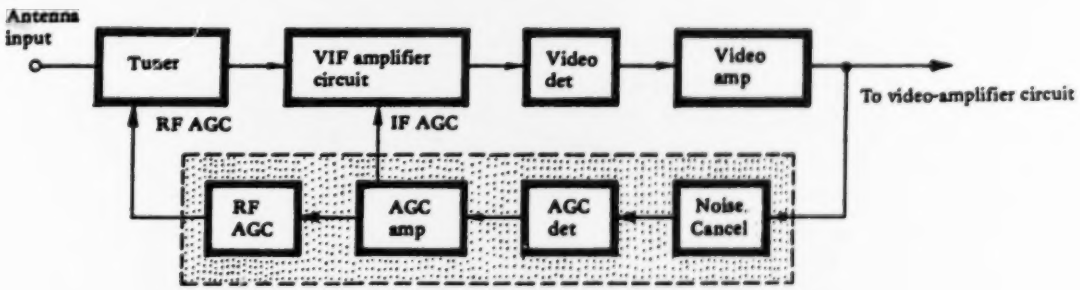


Figure 2-52
Block diagram of an AGC circuit

AGC action

Figure 2-53 shows a graph of the current gain (h_{fe}) vs the collector current of the transistor used in the AGC circuit. At first the current gain increases with the collector current, then after a certain collector current value, the gain decreases when the collector current is further increased. Thus the gain of the RF and VIF stages is altered by varying the collector current.

There are two opposite AGC actions used in changing the current gain of the transistors in the RF and VIF stages. These two methods are *forward* and *reverse* AGC. In forward AGC action the gain of the transistor is decreased by increasing the collector current. This is done by increasing the forward bias at

Figure 2-53
A graph of current gain (h_{fe}) vs collector current of a transistor used in an AGC circuit

the base of the transistor towards saturation. In reverse AGC action the gain of the transistor is decreased by lessening the collector current. This is done by reducing the forward bias at the base of the transistor towards cut-off. Forward AGC is more often used than the reverse AGC in solid-state receivers because the receiver tends to be more susceptible to overloading and cross-modulation during strong signals when the transistor is used near cut-off. In receivers using FETs in the RF stage, reverse AGC is commonly used.

How AGC voltage is taken out

There are three types of circuits which produce the AGC-control voltage: the average-value AGC circuit, the peak-value AGC circuit and the keyed AGC circuit.

These circuits must have the following requirements: insusceptibility to external noises and fast response to fast-changing levels of the incoming signals (airplane flutter).

In modern TV sets the keyed AGC and peak-value AGC are widely used.

Peak-value AGC circuit. Figure 2-54 shows a peak-value AGC circuit. Negative composite video signal taken from the emitter of Q1 is fed to the base of Q2. The output taken at the collector of Q2 is amplified positive sync signals. C2 is charged by these sync signals after they are detected by D1. Between the time interval of the sync signals, C2 discharges through R2.

If the time constant made by C2R2 is set longer than the horizontal scanning period, the voltage across C2 is constant and its value is proportional to the peak value of the sync signals.

This circuit, however, is easily affected by spike or pulse noises in the video signal with amplitudes greater than or equal to that of the sync signals. These noises cause AGC action even though the incoming signal remains constant. Thus these noises affect the gain of the circuits controlled by the AGC circuit. A noise-limiter circuit is placed at the input of the AGC circuit to prevent spike noises from affecting the AGC circuit.

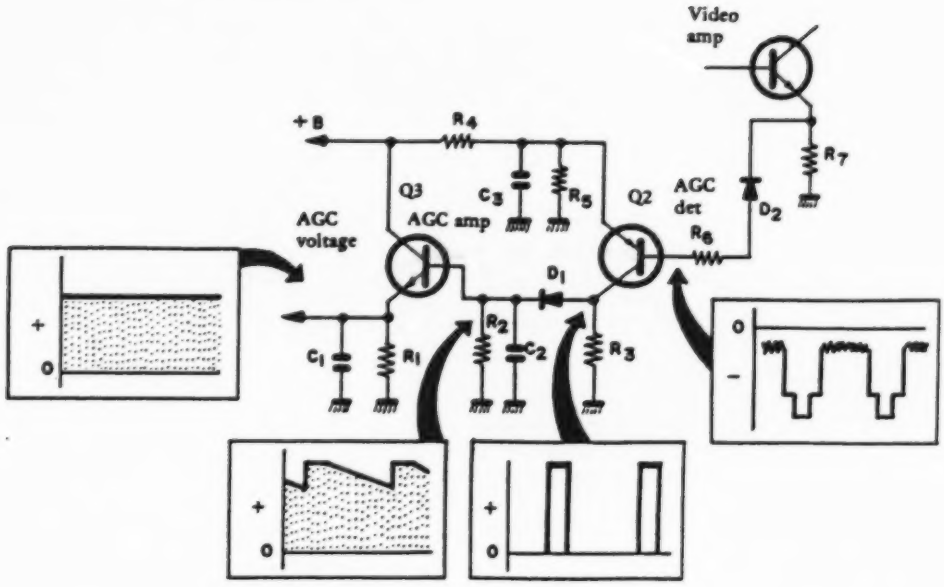


Figure 2-54
Peak-value AGC circuit

Keyed AGC circuit. Unlike the peak-value AGC circuit, the keyed AGC circuit is keyed on by the horizontal sync pulses. Thus the keyed AGC circuit is active only during the horizontal sync period. The advantage of this circuit is that it is not affected by pulse or spike noises in the video signal during the trace period. Furthermore, the time constant of the keyed AGC filter can be made shorter for faster response to airplane flutters.

Figure 2-55 shows a keyed AGC circuit. Negative video signal is taken from the emitter of Q1 (video amplifier) and applied to the base of Q2 (AGC detector). Horizontal flyback pulses from the flyback transformer are applied to the collector of Q2 through R14, C4 and D2.

Q2 conducts only during the presence of the horizontal flyback pulses at the collector and the sync signals at the base. The direction of the current flow is shown in the figure. This current flow charges C3 and sets the base bias of Q3 (AGC amplifier) to negative. When the strength of the video signal at the base of Q2 increases, C3 is charged more negatively. Thus the base voltage of Q3 decreases, increasing the collector voltage. The collector voltage of Q3 is the AGC voltage supplied to the base of the VIF amplifier transistor through R10. Thus the increase in the collector voltage of Q3 increases the base voltage of the VIF amplifier. Since increasing the base voltage increases the collector current, the gain of the VIF amplifier is decreased. Similarly, when the strength of the video signal at the base of Q2 decreases, C3 becomes less negatively charged. Thus the base voltage of Q3 increases and its collector voltage decreases. As a result, the AGC voltage decreases the base voltage of the VIF amplifier and increases the gain.

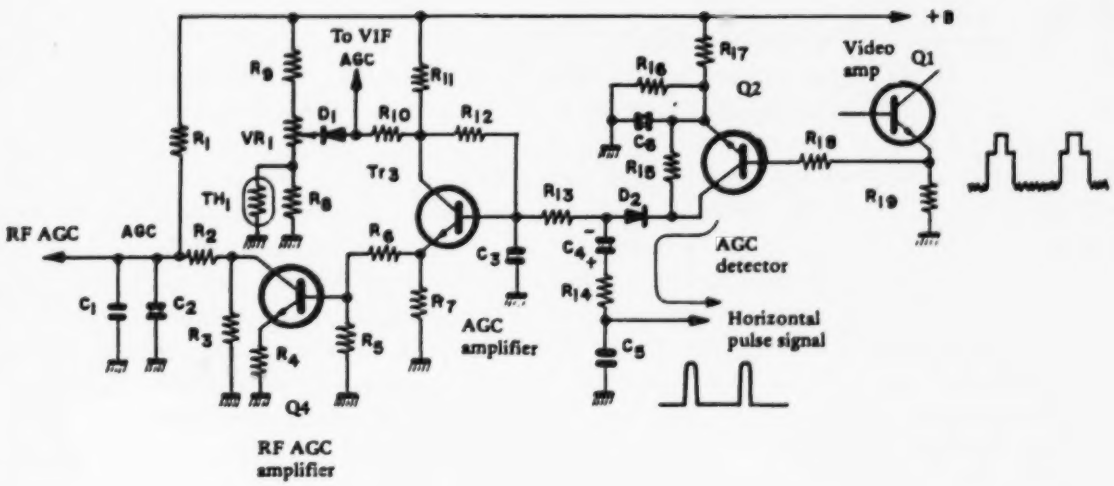


Figure 2-55
A keyed AGC circuit

Video-amplifier circuit

Function of the video-amplifier circuit

The function of this circuit is to amplify the video signal (mainly the luminance (Y) signal). The luminance signal is amplified to a magnitude sufficient to drive the colour CRT.

The driving voltage required by a colour CRT depends on its type. It is generally around 50 to 150 Vp-p. The output voltage of the video detector is about 1 to 2 Vp-p, so it has to be amplified 50 to 100 times by the video-amplifier circuit. Besides amplifying the Y signal, the video amplifier performs the following functions: a) distributes the composite video signals to the sync and the bandpass amplifier circuits; b) delays the luminance signal to synchronise its arrival to the colour CRT with the arrival of the colour signals; c) restores the DC component of the video signal; and d) compensates the distortion of the mid- and the high-frequency components of the video signal.

Block diagram of the video-amplifier circuit

As shown in Figure 2-56 the video-amplifier circuit consists of three to four stages. There are two ways of driving the colour CRT. One is called primary colour signal drive and the other is the colour-subtraction signal drive.

The video-amplifier circuit shown in Figure 2-56 is a five-stage amplifier, with the first amplifier stage included inside an IC. The first video-amplifier circuit distributes the video signal to the sync and bandpass amplifier circuits as well as to the succeeding second video-amplifier circuit. The contrast and the sharpness circuit, which controls the softness or sharpness of the picture, is included in the second video-amplifier circuit. The brightness, video-signal DC com-

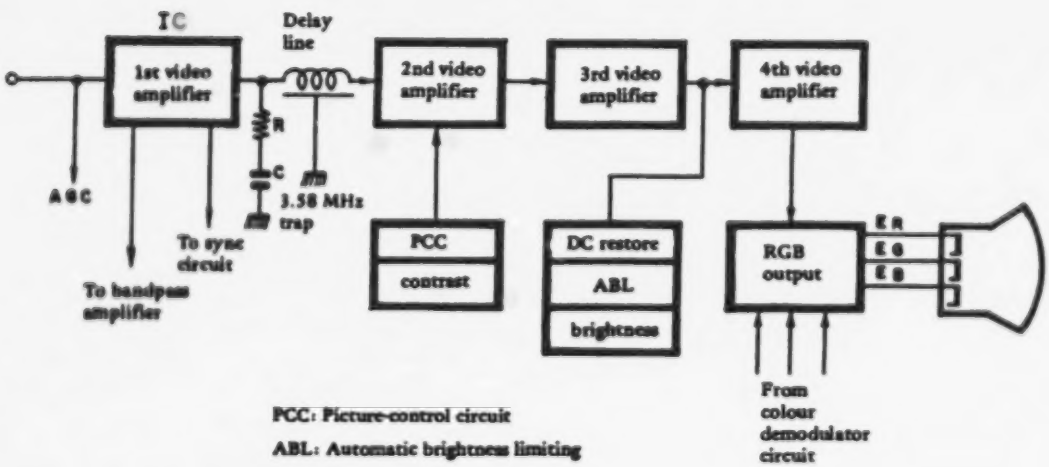


Figure 2-56
Block diagram of a video-amplifier circuit

ponent-restoring and ABL (automatic brightness limit) circuits are included in the third video-amplifier circuit. The ABL circuit prevents excessive anode current flow within the CRT.

To prevent the 3.58 MHz beat distortion, a 3.58 MHz trap circuit is placed between the first and second video-amplifier circuits.

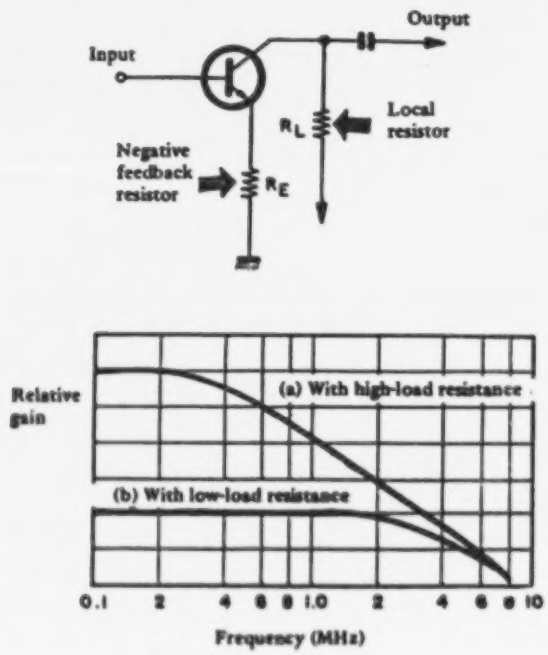


Figure 2-57
Function of a load resistor

Frequency response compensation

For the video-amplifier circuit shown in Figure 2-57, the load in the collector circuit is a low-resistance resistor. A low-resistance load enables the circuit to amplify the wide-band luminance signal. Negative feedback is also applied to the circuit to increase the bandwidth of the circuit. But because of stray capacitance due to circuit wirings and the input capacitance of the transistor, the gain in high frequencies is still less.

An inductor called a peaking coil, shown in Figures 2-58(a) and (b), is used to compensate the lesser gain of the circuit at high frequencies. The peaking coil forms a resonant circuit, the stray capacitances of the circuit boosting the strength of the high-frequency components of the video signal.

A small capacitor connected in parallel to the emitter resistor R1, as shown in Figure (c), is another way to compensate the lesser gain in the high-frequency component of the video signal. It reduces the negative feedback at high-frequency component, increasing the gain.

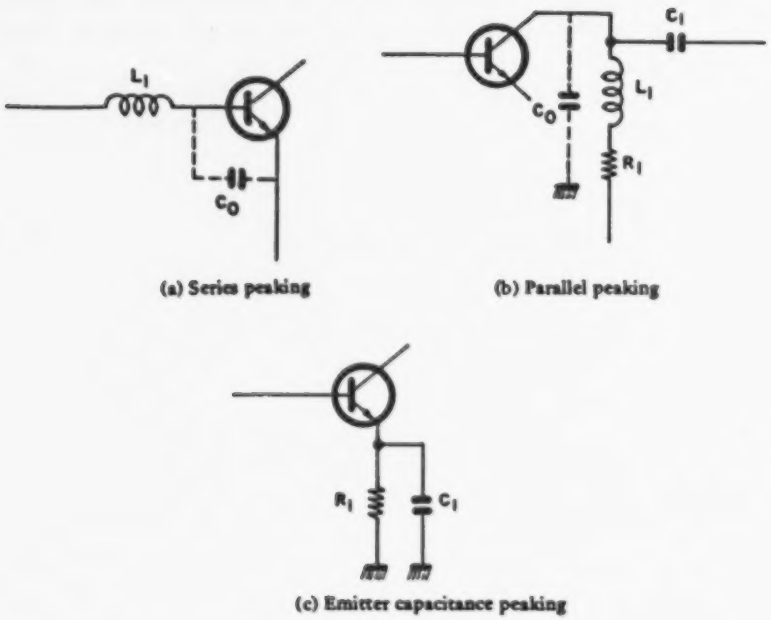


Figure 2-58
High-frequency compensation circuits

The value of the peaking coil and the capacitor will change the frequency of the resonant circuit. The load resistor and the feedback resistor determine the amount of frequency compensation. Sometimes a resistor is connected in parallel to the peaking coil to decrease the Q of the coil. It buffers excessive compensation.

Figure 2-59 shows an overall response of the video-amplifier circuit.

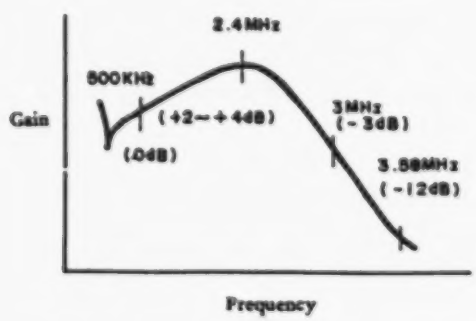


Figure 2-59
Frequency response in video-amplifier circuit

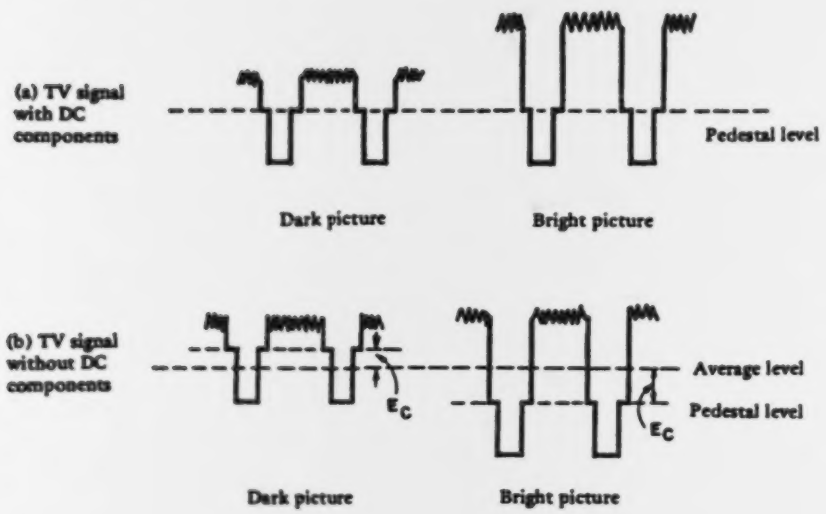


Figure 2-60
Video signal with/without DC components

Transmission of DC component

As shown in Figure 2-60(a), the pedestal levels of the video-detector output are constant in a TV signal. However, if the TV signal is amplified by an ordinary CR-coupled amplifier circuit, the DC component of the signal will be lost. When this happens, the pedestal levels of the sync signals of the brighter part of the video signal are not equal to the pedestals of the darker part of the video signal, as shown in (b).

Figure 2-61 shows an example. If a video signal with a big change in contrast is applied to the base of Q1, the collector voltage is greatly changed. The change in the collector voltage modifies the charging voltage of C3 (voltage across R5 or base voltage of Q2). The change in the base voltage of Q2 results in a change in pedestal level at output. When a video signal without constant pedestal levels, such as the one shown in Figure 2-62, is fed to the CRT, the white signal will be reproduced as a grey colour on the screen due to the lack in DC components of the video signal.

To prevent the loss of DC components from the video signal, one uses a direct coupling circuit or a resistor coupling circuit (a resistor is connected in parallel to the coupling capacitor). With these circuits the DC component of the video signal is coupled to the succeeding stages. However, even with these coupling circuits the DC component level is still insufficient. Therefore a DC restoring circuit is needed in the video-amplifier circuit. This sets the pedestal of the sync signals of the brighter and darker parts of the video signal to the same level.

Figure 2-61 shows a DC restoration circuit. This circuit is called the pedestal clamp. The horizontal sync pulses taken from the sync circuit is delayed by a time t by the delay circuit formed by L5, L6, C6 and C7. These delayed sync

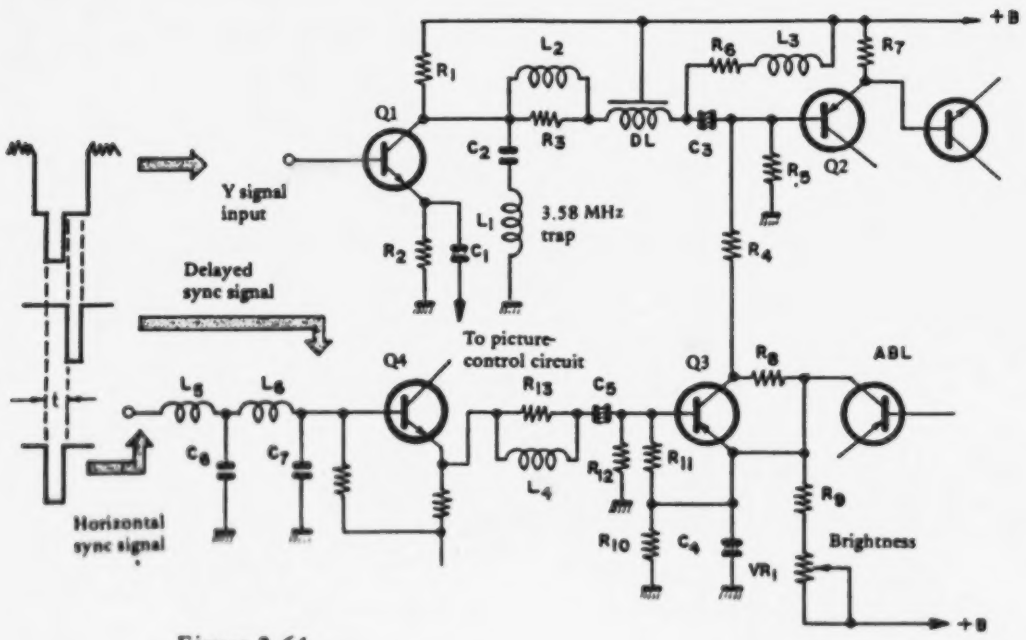


Figure 2-61
A DC restoration circuit

pulses are amplified by Q4 and Q3 before they are supplied to the base of Q2.

C3 is charged during the horizontal scanning period and discharges quickly when Q3 is turned on by the horizontal sync pulses passing through R6, power supply, R10, Q3 and R4. Therefore the base voltage of Q3 is always maintained at the constant level compensating the unevenness of the pedestal level.

Delay line

Figure 2-59 shows the frequency response of the video-amplifier circuit. Since

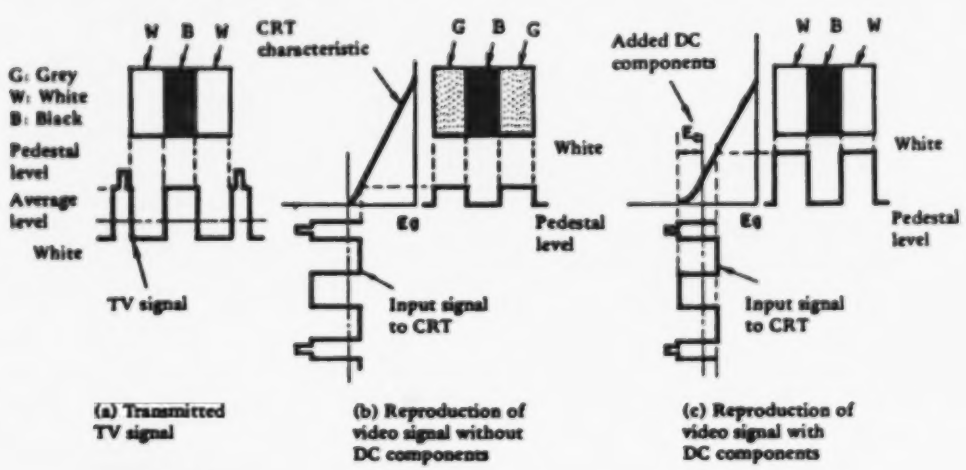


Figure 2-62
Video reproduction with/without DC components

the bandwidth of the chroma circuit is around 0.5 MHz, the difference between the bandwidth of the video-amplifier and chroma circuits results in a different processing speed for the video and chroma signals. The signal in the chroma circuit is delayed with respect to the signal in the wide-band video amplifier. This results in different time arrivals of the colour and luminance signals at the CRT and in a double image on the screen. The image produced by the Y signal will be superimposed and shifted a bit to the right of the image produced by the chroma signal. To synchronise the arrival of the two signals at the CRT, the Y signal should be delayed by around 0.8 to 1 usec.

Figure 2-63 shows the structure of a delay coil used for the delay line. The delay-line circuit can be a lumped parameter circuit or a distributed parameter circuit. The lump parameter coil is widely used, because it makes the delay circuit more compact and simple.

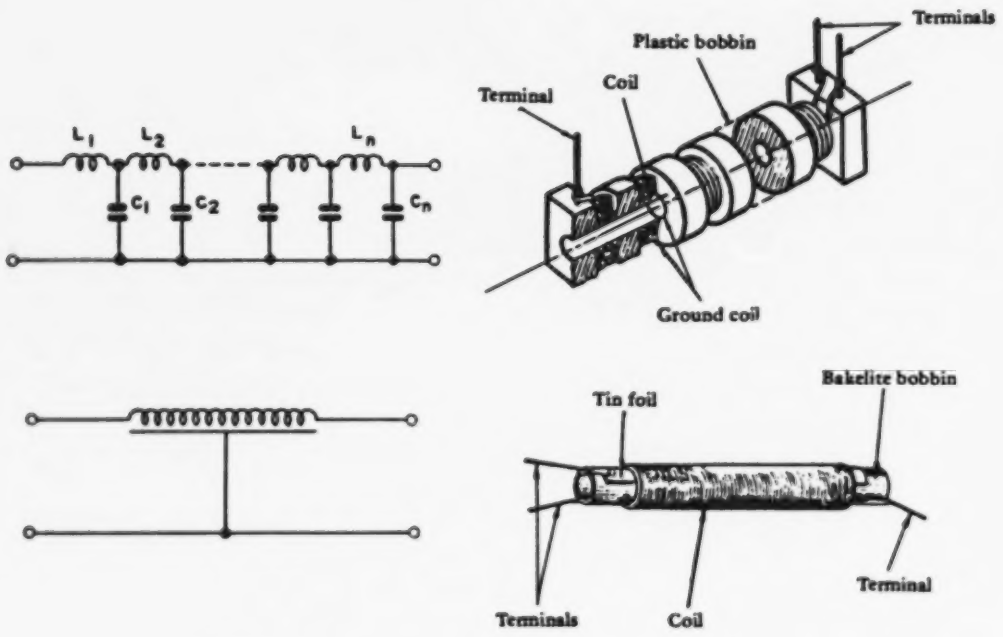


Figure 2-63
Structure of a delay coil

Sharpness-control circuit

As far as sharpness is concerned, human eyes are more sensitive to video-signal components with frequencies ranging from 1 to 2 MHz. The sharpness of the image on the screen is varied by controlling the negative feedback in the video-amplifier circuit. The negative feedback which controls the gain of the stage can be varied by adjusting VR1 in Figure 2-64.

The resolution of the image on the screen decreases at high-frequency video-signal components. This is due to the aperture characteristic of the CRT. A special compensation circuit is used to improve the aperture characteristic of the colour CRT.

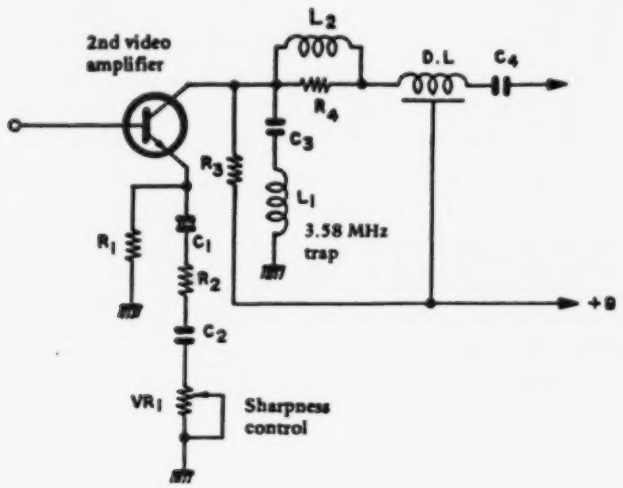


Figure 2-64
Video-sharpness circuit

Figure 2-65 shows an aperture-control circuit. The video signal corresponding to (1) is supplied to the base of Q. The inverted signal at the collector is differentiated by R1L1 and the resulting signal is shown corresponding to (2).

This signal is further differentiated by C1R4, resulting in the signal corresponding to (2)'. The signal from the emitter is summed with this signal to produce the signal corresponding to (4), which has an overshoot and a pre-shoot.

VR1 combined with C4 varies the amount of negative feedback which controls the amplitude of the differentiated signal at the collector of Q.

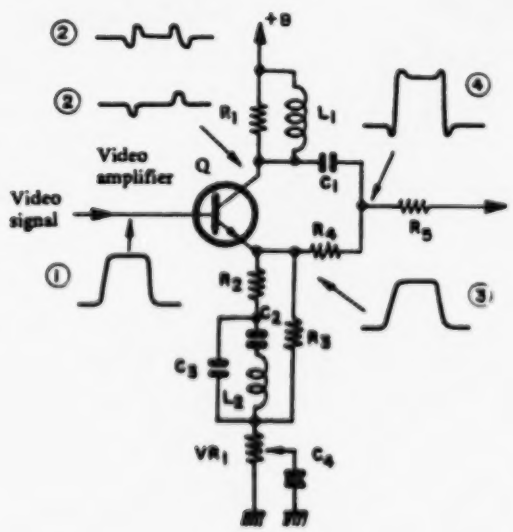


Figure 2-65
An aperture-control circuit

Contrast and brightness control

Contrast control. There are two ways to control the contrast of the image on the screen. One is to vary the amount of negative feedback in the video amplifier to control the gain of the stage; the other is to control the strength of the video signal at the input of the video amplifier.

Figure 2-66 shows two contrast-control circuits. In both cases, the contrast is varied by adjusting VR1. For the circuit in (a), the strength of both DC and AC components in the video signal is varied. Thus the brightness and the contrast of the image are both varied by VR1.

In Figure (b) the DC component is coupled to Q2 by R3. The value of R3 is negligible compared with the value of R4. Thus, adjusting VR1 will not cause a noticeable change in the brightness of the picture. However, since C1 offers a low-impedance path to AC signals, the AC component of the video signal coupled to Q2 can be varied by adjusting VR1. Thus the brightness of the image on the screen remains relatively constant while varying the contrast.

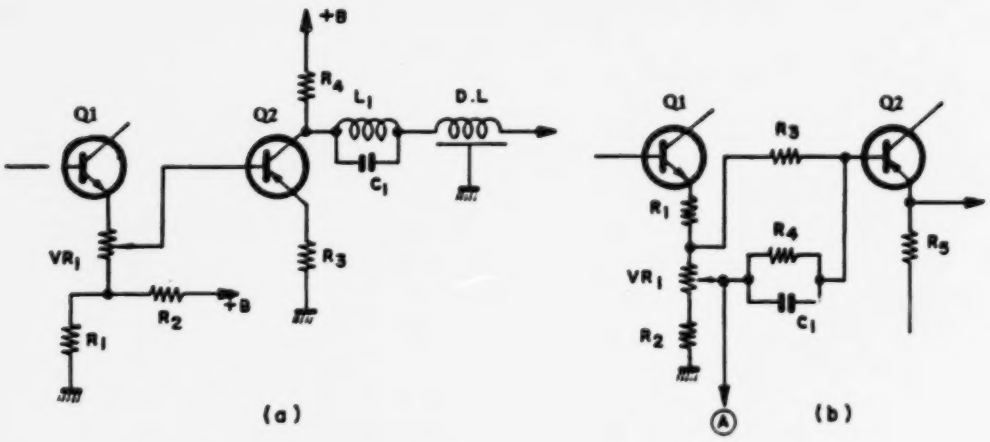


Figure 2-66
Contrast-control circuits

In some colour receivers the contrast control is combined with the colour saturation control. The voltage at the wiper of VR1 [point (A) in (b)] is tapped and used as a control voltage for the bandpass amplifier circuit. Thus, varying the contrast also varies the colour saturation. This gives the proper colour saturation for different image contrast levels.

Brightness control. The brightness of the raster in colour CRTs can be varied by changing either the base or the emitter voltage of the video-amplifier transistor. Figure 2-67 shows two brightness-control circuits.

The base voltage of the video-amplifier transistor is controlled in the circuit in (a). In this circuit two variable resistors control the brightness. VR2 is for the brightness control, VR1 for the sub-brightness control. VR1 determines the maximum brightness.

Figure (b) shows a circuit that controls both the base and emitter voltages of the video-amplifier transistor. The brightness is controlled by VR2, which is

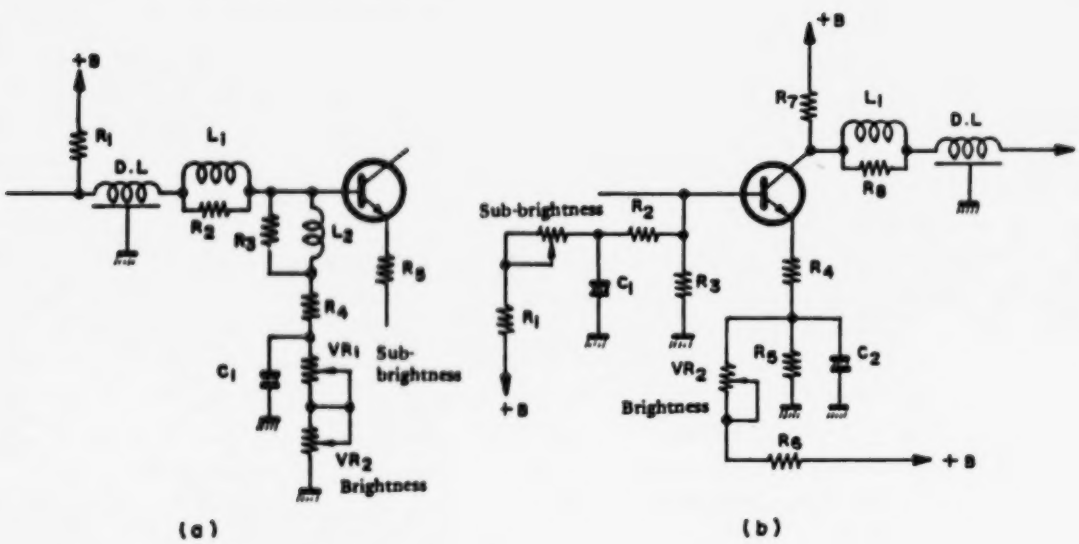


Figure 2-67
Brightness-control circuits

connected to the emitter circuit. VR1 is for the sub-brightness control and is connected to the base circuit.

Since the video-amplifier output is directly coupled to the CRT, the cathode voltage of the colour CRT is also varied by the brightness control. Hence the brightness of the raster on the screen is controlled.

Automatic brightness-limiting (ABL) circuit

This circuit protects the horizontal output transistor from being damaged by high beam currents at excessive brightness. Excessive brightness results in large anode current in the CRT, which overloads the high-voltage circuit.

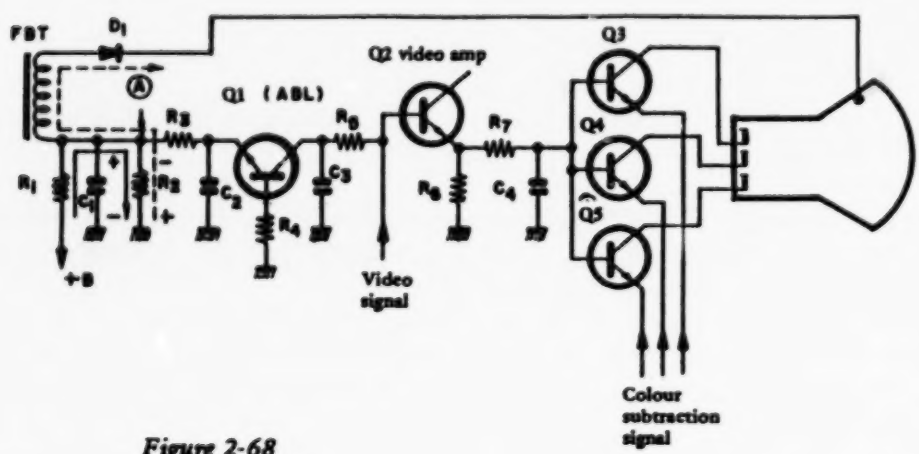


Figure 2-68
An ABL circuit

The ABL circuit detects changes in the current within the FBT (flyback transformer). When an excessive flow is detected, a negative feedback is supplied to the video-amplifier circuit to automatically reduce the brightness, reducing the current through the FBT.

Figure 2-68 shows an ABL circuit. The current from the B+ supply indicated by the solid line flows through R1 and R2 and produces a positive voltage at point (A). The anode-current flow is indicated by the dashed line. The polarities of the voltages produced by the anode and B+ supply currents across R2 are opposite. The magnitude of the voltage produced by normal anode currents across R2 is less than the magnitude of the voltage produced by the B+ supply current. Thus, during normal conditions point (A) is maintained at a positive potential which keeps Q1 in cut-off.

When the brightness becomes excessive, the anode current increases such that the voltage it produces across R2 sets point (A) at a negative potential. This turns on Q1. As Q1 conducts, the base voltage of Q2 decreases. Consequently the base voltages of Q3, Q4 and Q5 decrease. This increases the cathode voltage of the colour CRT, decreasing the anode current as well as the brightness.

Blanking circuit

White diagonal retrace lines will appear on the screen if the CRT is on during the horizontal and vertical retrace period. The blanking circuit serves to turn off the CRT during the retrace time to eliminate the diagonal lines on the screen.

Figure 2-69 shows a blanking circuit. Positive horizontal and vertical pulses are applied to the base of Q1 during the retrace period. These pulses keep Q1 on during the retrace period. When Q1 conducts, the voltage at point (A) approximates the B+ voltage. This forward-biases D4. The voltage drop across R7 and R6 produces a positive voltage at the base of Q2. This switches off Q2. D3 clips off the negative parts of the vertical and horizontal pulses.

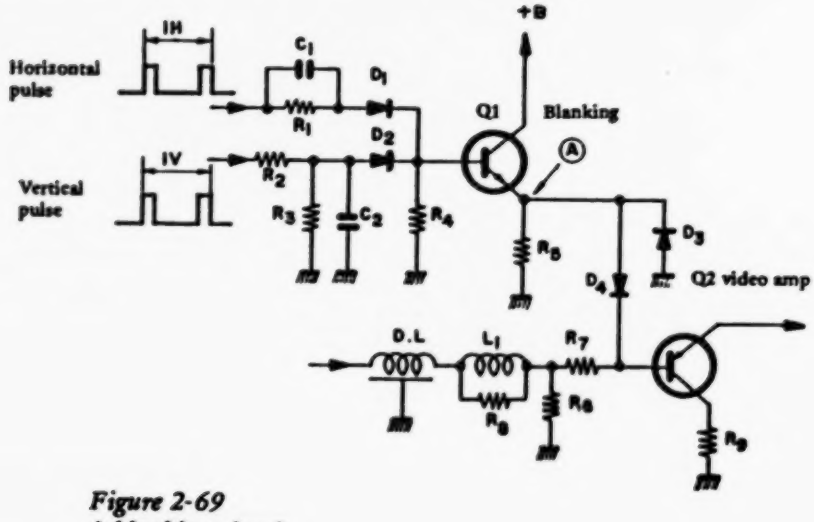


Figure 2-69
A blanking circuit

Actual video-amplifier circuit

Figure 2-70 shows a primary-colour signal-drive video-amplifier circuit. It consists of four stages, including the amplifier circuit within the IC.

The composite video signal taken at the cathode of D1 is fed to the first video-amplifier circuit inside the IC. The low-pass filter and the 4.5 MHz sound-trap circuits are located at the input circuit of the IC. The output is taken from pins 11 and 13. The signal from pin 13 is supplied to the delay line (DL) preceded and succeeded by matching coils L4 and L5, respectively. The signal furthermore passes through the 3.58 MHz trap circuit to separate the 3.58 MHz chroma signal before the video signal is fed to the base of Q1.

The ABL circuit, which is in the base circuit of Q1, is controlled by VR5.

The amplified video signal at the collector of Q1 is differentiated and mixed with the signal from the emitter of Q1 and then fed to the base of Q2. This circuit is the picture-sharpness circuit discussed in the section on "Sharpness-Control Circuit." The output at the collector of Q2 is fed to the base of Q4. Q4 is controlled by Q3. Blanking pulses are supplied to Q3 and switch on Q3 during retrace periods. When Q3 conducts, the base voltage of Q4 is driven to a positive value, which turns off Q4. This circuit is the blanking circuit.

The output at the emitter of Q4 is fed to the emitter circuits of the R, G and B primary-colour signal-output transistors Q5, Q6, and Q7, respectively. The colour-subtraction signals are independently supplied to the bases of Q5, Q6 and Q7. The matrixed colour and luminance signals are taken from the collectors.

In the colour-subtraction drive system, the luminance (Y) signal alone is coupled to the cathode of the CRT from the collector of the last video-amplifier transistor.

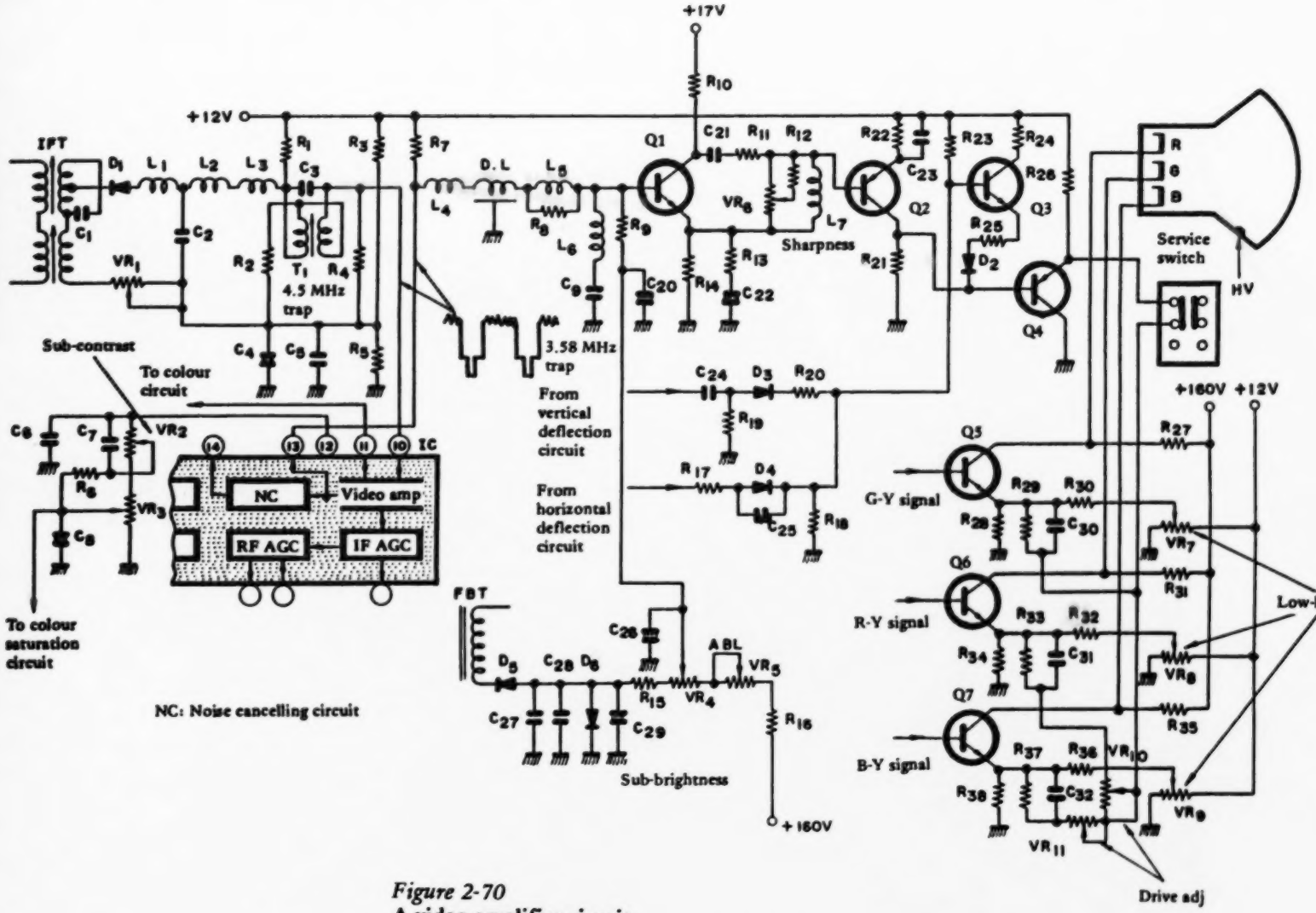


Figure 2-70
A video-amplifier circuit

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